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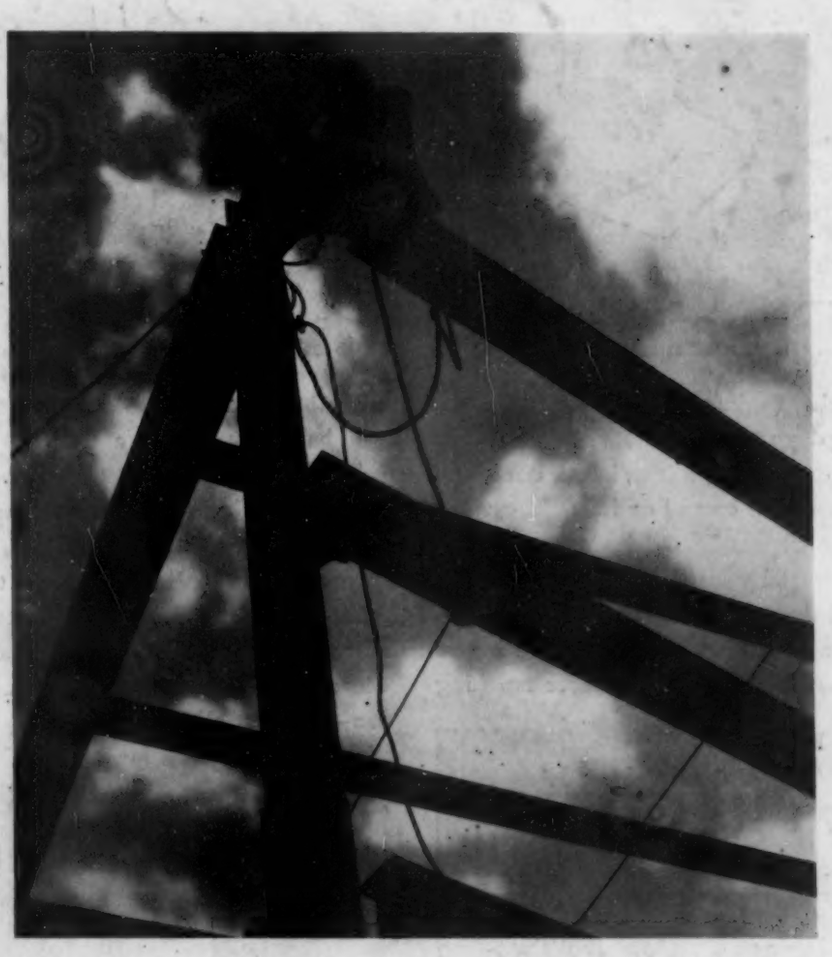

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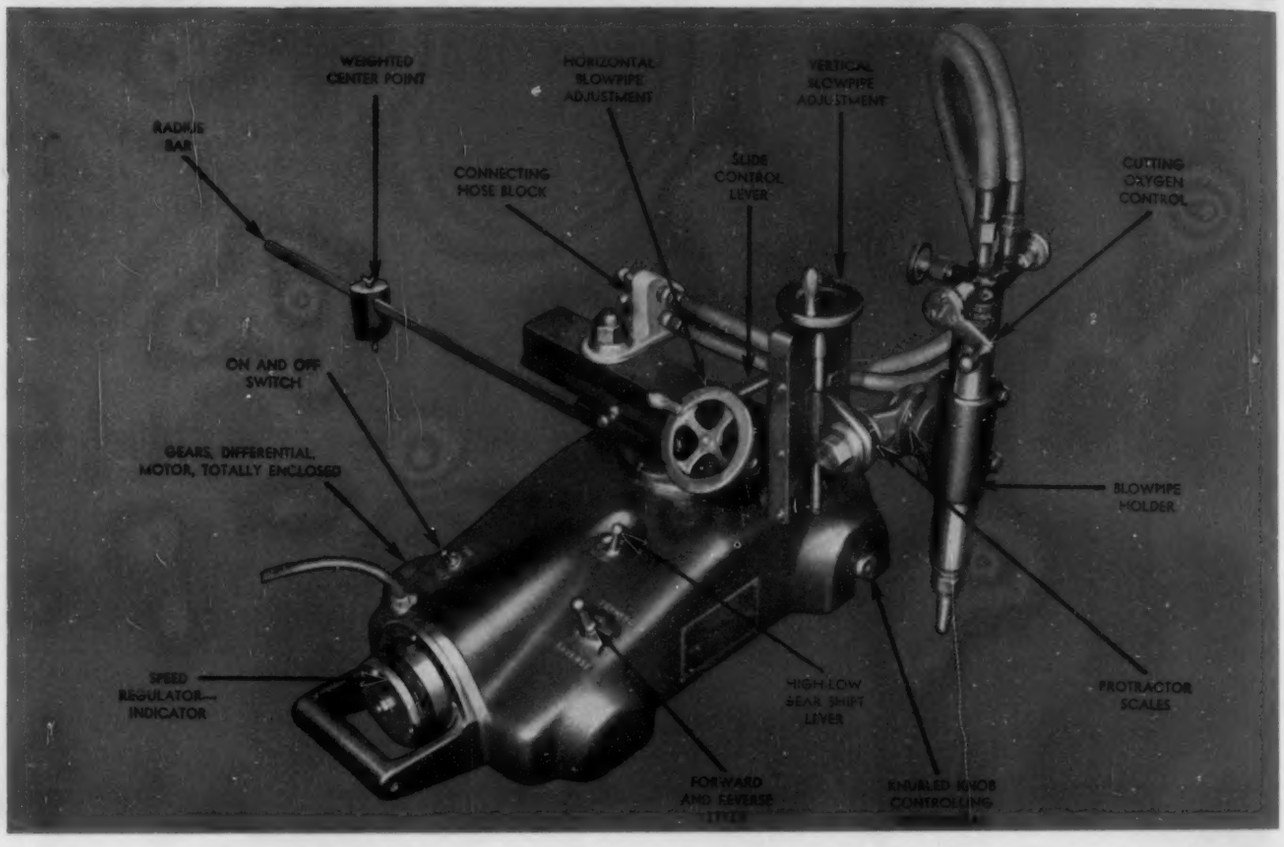

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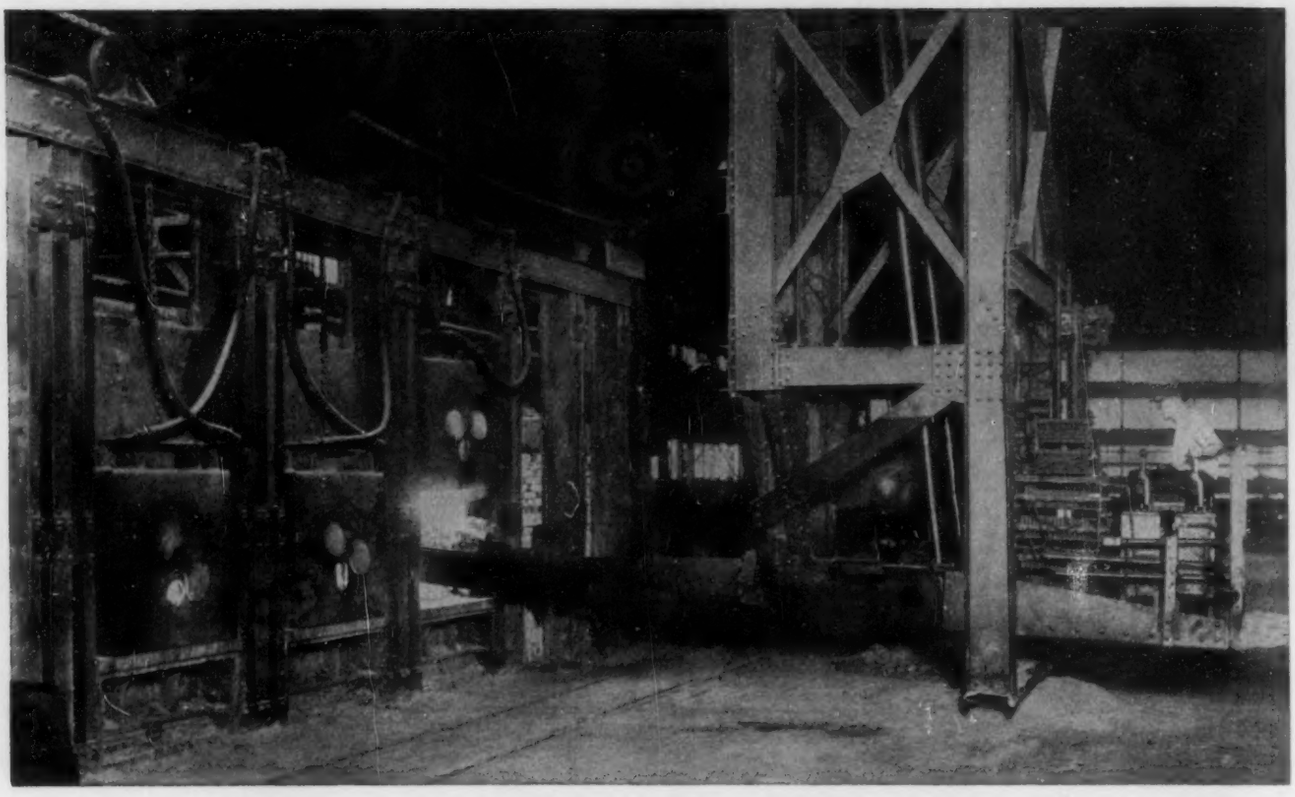


Open-Hearth Steel Practice Is Analogous to Steel Welding

Metallurgy of Oxyacetylene Welding of Steel*

By J. H. CRITCHETT†

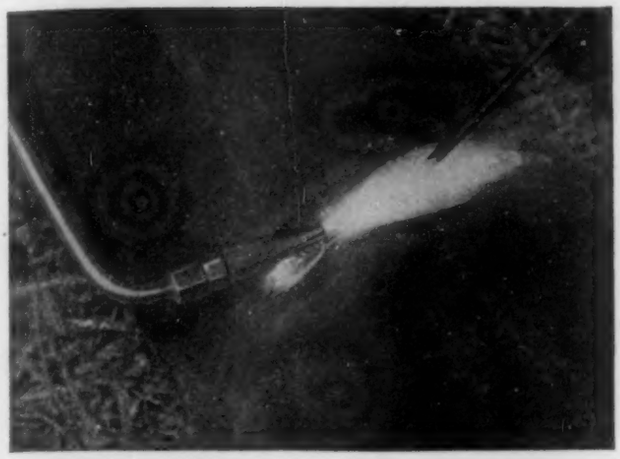
OXYACETYLENE welding of steel involves heating the metal from room temperature up to and beyond its melting point and hence in a metallurgical study of the process it is necessary to consider all of the effects—physical, metallurgical and chemical—that can take place in steel over that entire temperature range both in the solid and liquid conditions. The study, therefore, covers physical changes such as expansion and contraction, metallurgical effects such as crystallization, heat treatment and the effect of alloys and all the chemical reactions of liquid steel with its surrounding materials. The fact that welding usually progresses along a joint or fracture and that surrounding the point of welding all temperatures are present from normal to that of liquid metal, adds greatly to the difficulty of accurate metallurgical study of the system.

The simplest phenomenon which happens to solid steel on heating is, of course, expansion. This is, in the initial stages and in unrestrained metal, purely a change of volume and in ordinary steels is a completely reversible change regardless of the rate of heating or cooling. At the same time that it is expanding, the steel becomes increasingly soft, ductile and weak, a fact that has both advantages and disadvantages. Due to this fact stresses become dissipated and advantageously spread over a wide area because of the ease with which the steel can stretch and yield. Especially is this true in oxyacetylene welding where a considerable area is heated at one time. On the other hand, the low strength at these elevated temperatures makes it necessary to be certain that the piece being welded is free to move so that an undue load is not placed on the hot steel. Particular attention must be paid to the final welds of a closed structure or in joining a light to a heavy section in order to prevent the locking up of stresses in the structure or even, in extreme cases, rupture of the weld metal.

When plain carbon steel is heated somewhat higher to a temperature, called the recalescence point, which depends on the composition of the steel, but lies in the neighborhood of 1400 deg. F. or a bright red heat, it goes through a metallurgical change of the greatest importance. At this temperature the carbon, which at lower temperatures has existed as discrete particles of iron carbide mixed with pure iron, goes into solution in the iron and at higher temperatures remains in solid solution—a condition analogous to salt dissolved in water. On slowly cooling down through this tempera-

* Read at the 35th Annual Convention, International Acetylene Association, Pittsburgh, November 14, 15 and 16, 1934.

† Vice-President, Union Carbide and Carbon Research Laboratories, Inc.



The Heat Effect of the Oxyacetylene Flame Can Be More Easily Controlled Than the Effect of Any Other Method of Welding

ture, the carbon is again precipitated or thrown out as iron carbide. The manner in which the precipitation takes place and hence the condition of the steel at lower temperatures, is profoundly affected by the rate at which the cooling takes place. When rapidly cooled, the steel is left in a relatively hard and brittle condition whereas slowly cooled through this temperature, it is soft and ductile.

Another effect which takes place at about the same temperature is recrystallization. When heated much above the recalescence point, steel crystals tend to grow in size to an extent depending on the length of time at the temperature and the amount the temperature exceeds the recalescence point. If, however, the temperature is just above the recalescence point and the time short, the action results in small crystals, a condition which generally means superior physical properties. Another type of recrystallization takes place in steel which has been stressed, a condition found in practically all metal that has been rolled in manufacture or formed for fabrication. When stressed steel is heated even below the recalescence point, it recrystallizes in a manner dependent on the amount of stress present. The higher the stress, the lower is the temperature at which recrystallization takes place and the finer the resulting crystals.

As is well known, steel reacts with the oxygen of the atmosphere at all temperatures. At ordinary temperatures the reaction so commonly recognized in rusting takes place slowly. At higher temperatures the tendency for iron to react with oxygen markedly increases, resulting in an adherent oxide scale which affects greatly the steel just below the surface. At the junction of scale and steel, the carbon of the steel begins, when heated, to react with the oxide of the scale, first at the surface, the carbon being converted to gaseous carbon monoxide which is eliminated. As the surface of the metal becomes decarburized, more carbon from below the surface migrates through the solid steel to the decarburized surface, carrying on this reaction still further so that, in the course of a relatively short time, the carbon may be almost completely removed from the steel to an appreciable depth.

When the metal becomes molten, all these reactions can take place at an even faster rate. Iron oxide becomes soluble in the liquid and hence is in a condition to react much more rapidly with carbon and certain other elements contained in the molten steel. At this stage the analogy between the reaction in welding and in an open-hearth steel-making furnace is quite close and it would be helpful, therefore, to consider what does take place in such a furnace.

The usual charge for an open hearth is a mixture of slag-making materials, steel scrap and pig iron in such proportions that the resultant mixture will have a carbon content of about $1^1/_2$ per cent. After covering the bottom of the furnace with the slag materials, the steel scrap is charged and then the pig iron on top of the steel. The reasons for the use of pig iron in the charge are partly economic and partly due to the well-known fact that carbon greatly lowers the melting point of iron. By placing the pig iron on top of the charge, it gets the first effect of the heating flame; becomes molten; trickles down over the lower carbon steel scrap; mixes with or fluxes the higher melting soft steel, thus enabling the charge to be brought to a molten condition much more rapidly than with a charge of soft steel alone.

At the end of the melting period, the slag has risen to the surface and overlies a liquid bath of steel containing slightly less carbon than the mixture charged, but still higher than the carbon content finally desired. A reaction goes on between the carbon in the liquid steel and the iron oxide, derived partly from the rust on the scrap, partly from the flame and partly from added iron ore. The reaction gives the bath a gentle boil which is maintained by additions of iron ore until the carbon has been brought down to the desired figure.

The rôle of one other element, manganese, must also be taken into account here. It is generally accepted in the steel industry that the addition of a small amount of manganese to the initial charge is very beneficial. This manganese becomes oxidized, passes to the slag, is reduced again by the carbon content of the steel bath and redissolved in the steel and repeats the cycle. However, in going from metallic manganese to oxide in the bath, the oxide combines readily with nonmetallic impurities and carries them with it out of the steel bath into the slag. In this way the manganese acts as a very effective cleansing agent on the liquid metal.

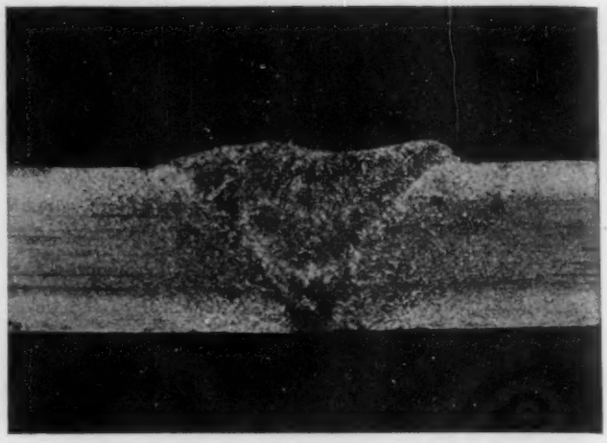
Perhaps the simplest product of an open-hearth furnace is so-called rimmed steel such as would be produced if the furnace were tapped at the end of the operation which has just been very roughly described, except for the addition at the end of a small further amount of manganese. It is, however, simple only in the number of constituents involved. Actually, it is a type of steel that calls for the highest skill of the open-hearth melter. It depends primarily on a definite content of iron oxide

A Weld in the Making. The Flame High in Acetylene Coming from the Tip (Bottom of Cut) Melts the Rod (Top of Cut), Conditions the Metal Surface and Anneals the Completed Weld (Not Visible) Behind Rod

for correct behavior in the mold and the content of oxide varies with carbon content and temperature of the steel and the size of the ingot being cast. If this type of steel is tapped from the furnace with the correct degree of oxidation for its carbon content and temperature and poured into an ingot mold, there is a gentle effervescing due to the reaction between the oxide and carbon contents of the liquid steel which results in an ingot with an exceedingly clean and dense surface but filled with cavities or blowholes toward its center. Such a steel is well adapted to the production of many articles which must have a good surface. The strength and other physical properties that this type of steel can have even when perfectly made are strictly limited by the fact that only low carbon steels can be rimmed and the presence of alloying elements is prohibited by the nature of the operation. When this type of steel is imperfectly made, the less said the better, for it is subject to a host of ills and becomes a very low-grade product.

If steel is required having higher physical properties than it is possible to obtain from rimmed-product, the open-hearth process is changed accordingly. The charge is chosen in the same way and the process operates as in the case of rimmed steel to the point where the carbon has been brought down to the desired level. At this time the reaction between iron oxide and carbon is stopped by the addition of 15 per cent ferrosilicon and spiegel or silico-manganese. The silicon and manganese of these additions reduce all of the iron oxide of the steel bath and when the additions are properly made, the solid products of the reaction, manganese oxide and silica, effectively flux out the last of the impurities in the bath. Additions are then made to bring the steel to the desired analysis. In the case of plain carbon steel these additions are ferro-manganese and ferrosilicon, the first being added to the furance shortly before tapping and the latter to the ladle as it fills from the furnace. Other additions required in the case of alloy steels are made at the same time. When such a steel is cast into the ingot mold, it lies quiet and freezes first against the ingot mold and from there inward to the center. Since the outside dimension of the ingot is established by the mold at the time the steel is poured and since with such a deoxidized or killed steel there is no gas evolution to form blowholes, the shrinkage in volume during the freezing operation results in a pipe or cavity in the center of the top of the ingot but the balance of the ingot is exceedingly dense and solid.

A Neutral Flame Fusion Weld Shows This Type of Grain Structure. Compare This with That in the Following Illustration



The Area of Small Grain, a Result of Carburizing Flame, Is Advantageous Because of Greater Ductility and Toughness

The outline of principles involved has been necessarily cursory and abbreviated but it is hoped sufficiently clear for the purposes of this paper. Let us see how they apply to oxyacetylene welding, giving attention first to welding rods and weld metal.

The first oxyacetylene welding of good quality was done with low carbon steel welding rods containing a minimum of other elements. The operation is quite analogous to the making of rimmed steel. In the heating-up of the base metal and the welding rod to the fusion point, both become coated with iron oxide, or scale. Several effects resulting from this fact have a direct bearing on the manipulation during welding and on the quality of the finished weld. First, the scale on the surface of the metal melts at a lower temperature than the steel itself, hence must be removed from the surface in order to get adhesion between the added metal and the base metal. The endeavor to be certain that this had been accomplished led to the melting of a considerable amount of base metal, giving a wide weld and excessive consumption of welding gases. Also, in order to make sure that this liquid iron oxide was completely eliminated from the weld, it was necessary to carry the temperature of the metal well above its melting point in order to obtain the liquidity that comes with higher temperatures. Further, the oxide dissolved in the metal reacted to some extent with the carbon, giving rise to blowholes, and the complete absence of silicon, manganese and other deoxidizing elements prevented a cleaning action such as goes on in an open-hearth furnace during the manufacture of high-grade steel. The carbon content of the rod had to be low to avoid excessive reaction between it and copious amounts of iron oxide that were present which would have led to a serious number of blowholes in the weld; the scale on the surface of the base metal effectively decarburized it, still further lessening the amount of strength-giving carbon in the weld; and the sluggish flowing qualities of the substantially pure iron weld metal led to the ripple type of weld since the metal had to be blown into place. In spite of all these difficulties and what now seems like welds having a very low order of strength, these welds served the early days of the industry well. To get good welds in those early days required a high degree of skill on the part of the welder and, therefore, led naturally to the temperamental nature of that worthy gentleman.

With growth of the welding industry and increased knowledge of its difficulties and needs came realization of the important rôle played by the rod aside from that of simply supplying metal to fill the scarf or vee. Rods

were devised containing the elements on which the steel manufacturer relies for the production of high-grade steel. By the addition of silicon and manganese the gas-forming reaction between carbon and iron oxide was minimized and replaced by a reaction between iron oxide and these metallic elements. Since the products of the reaction are solid, they do not result in blowholes and with the proper balance between the silicon and manganese contents in the welding rod, the ratio of silica to manganese oxide is controlled so as to produce a fluid slag which readily floats to the surface of the metal, effectively cleansing the weld metal as it does so and blanketing it against further oxidation. Eliminating the causes of the carbon-iron oxide reaction makes it possible to increase the carbon content of this type of rod and consequently of the weld metal to a figure comparable to the usual structural steel. As a consequence this type of rod yields materially higher strength as well as sounder welds. The strongly reducing elements in the rod remove the scale on the base metal without leading to further troubles, thereby presenting a clean surface for the weld metal to adhere to, making it unnecessary to melt deeply into the base metal. Further, the increased carbon, silicon and manganese in the weld metal materially lower its melting point so that it flows well and is easily placed where desired. All of these factors reduce the strain on the welder and the amount of work that the welding flame must do, leading to better technical results and, equally important, lower costs.

More recently a further advance has been made, this time in the technique of welding which, coupled up with the improved rod, makes modern oxyacetylene welding a very different procedure from that of the early days.

By using a carburizing or excess acetylene flame, the welding blowpipe is made to perform an added function over the usual preheating of the base metal and melting of the rod. The procedure depends on the fact that hot steel readily absorbs carbon, that high-carbon steel has a much lower melting point than low-carbon steel, that carbon very effectively reduces iron oxide, and that carbon disperses or migrates through hot steel at a rapid rate.

Using the carburizing flame for welding and directing the flame backward over the completed weld but in such a way that the excess acetylene flame touches the scarf or vee in advance of the welding puddle, serve first to reduce any iron oxide that may be on the surface of the metal. The reduction of the oxide leaves a very porous spongy type of iron which very readily absorbs carbon from the flame and the melting point falls as the carbon increases until with fully carburized iron it is nearly 700 deg. F. (684 deg. F. to be exact) below the melting point of carbon-free iron. This simple procedure thus serves to eliminate the trouble-making gas-producing scale at a point in advance of the welding operation so that blowholes from this source are prevented, and adds an appreciable amount of strength-giving carbon to the surface of the base metal which, without this treatment, would have been decarburized by its oxide surface. Moreover, the highly carburized low melting point surface of the scarf is easily brought to a sweating condition by advance of the welding operation without any particular attention being paid to it by the welder. This condition is perfect for forming the union between the liquid metal from the rod and the base metal. There is no need for melting into the scarf to ensure the presence of clean metal for this union and the welder's attention needs to be directed mainly to the operation of melting the rod. As a result, the width of the groove need not be as great as in earlier methods, hence less rod must be melted to fill it and this, together with the elimination of melting the scarf, leads to rapid easy welding at a reduced cost for welding materials. Needless to say, the high carburized surface of the scarf is rapidly absorbed by the added metal and the carbon diffused uniformly through the weld while still at a higher temperature giving a uniform strong and ductile weld metal.

Another real advantage derived from this type of welding is the ease with which it can be made semi-automatic for certain applications. The reduced attention required from the welder at the focal point of the welding enables construction of an apparatus by which the rod is gravity fed as needed and with several flames each designed to carry out a particular function of the operation. As would be expected, all this leads to an ease and speed of welding impossible under earlier methods.

In addition to consideration of the weld metal, metallurgical study of welding must also take into account the effect of heat on the base metal. Since at the point of welding all temperatures may be present from that of liquid metal to steel at normal temperature, these effects may be quite complicated. In the case of oxyacetylene welding, the considerable area covered by the heating flame brings quite an amount of steel to temperature, such that various changes take place but the ease with which this source of heat can be manipulated and directed where desired gives the process more control over these conditions than is possessed by any other system of fusion welding.

As pointed out in the early part of this discussion, heating of steel brings about three major effects. First is the simple case of expansion and contraction. Here the oxyacetylene method of welding has the distinct advantage of placing all of the filler metal in the groove at the same time. This enables the welder to allow for expansion needs quite completely since contraction is not restrained by metal put in during an earlier pass. Also, by playing the welding flame backward over the completed weld, the rate of cooling can be reduced, giving the structure the maximum possibility of adjusting itself and distributing the strains incident to contraction.

The effect of a higher temperature applied to metal results in heat-treatment, that is, the absorption of iron carbide into solid solution followed by reprecipitation of the carbide on cooling down. In oxyacetylene welding this effect is distributed over a considerable area and due to the retarding of cooling by the blanket of welding flame, the steel passes through the recalescence point at a very slow rate, which leads to the best possible toughness and ductility.

The last effect of heat on metal that must be taken into account is recrystallization which is distinct from heat-treatment in that it takes place only in stressed or cold worked metal and at a temperature below that at which the material can be heat-treated. In the case of oxyacetylene welding this area again is wide, hence the zone in which the metal is recrystallized to a fine state is relatively large. This condition is, of course, very advantageous since the area of small crystals is considerably more ductile and tougher than the original steel.

A little consideration shows that all of the effects discussed so far are present in all systems of fusion welding. For a long time oxyacetylene welding engineers had recognized the results of these effects and had paid sufficient attention to them to devise generally satisfactory answers. More lately codes covering welding have had included in them expedients for meeting the difficulties but the provisions do not take sufficient account either of the earlier experience or peculiar features

of oxyacetylene welding. Probably we in the gas industry have ourselves to blame very largely through failure to present our case with sufficient force and convincing data before the code bodies. While of undoubted value, it seems that too much reliance should not be placed on these code procedures as ensuring safe construction under all circumstances. The final answer in any structure can only be arrived at through careful attention to all the metallurgical principles involved and in practice may be quite a different answer for a large or complicated structure than would be indicated on small test pieces. From the oxyacetylene point of view the conditions surrounding welding minimize the value of the code expedients or even make them inoperative in some cases. To this extent recent welding code provisions have not been helpful to oxyacetylene welding first by creating an undeserved faith in certain types of electric welding, and then by placing unnecessary handicaps in the way of the oxyacetylene process. However, the pendulum often swings wide but it always comes back and it is very probable that we are now at a position in the cycle from which we will see a steady climb in the appreciation and more general use of oxyacetylene welding.

Stress-Relief of Fusion-Welded Pressure Vessels*

By D. S. JACOBUS†

THERE is no subject bearing on the construction of fusion-welded pressure vessels on which there is such a wide variation of opinion as on the conditions which make it necessary to stress-relieve the joints. The A. S. M. E. Code requires that the stresses be relieved in certain cases by heating uniformly to at least 1100° F., and up to 1200° F. or higher if this can be done without distortion, and holding the vessels at that temperature for a period of time proportioned on the basis of at least one hour per inch of thickness. The Code covers the welding of plain carbon steels in which the carbon content does not exceed 0.35 per cent. All welded drums for power boilers and all pressure vessels employed in the most dangerous service are required to be stress-relieved, but the Unfired Pressure Vessel Code sanctions the use of quite a wide range of fusion-welded vessels without stress-relief.

The temperature specified for stress-relieving the welds does not refine the grain structure. In vessels made of alloy steel or in which the carbon limit exceeds that specified in the Code, it is necessary in many cases to refine the grain adjacent the welding by heating the vessels to above the critical temperature after welding. The remarks which follow apply to the stress-relief of vessels constructed of plain carbon steel in accordance with the rules of the A. S. M. E. Code where the carbon content does not exceed 0.35 per cent and may not apply to vessels constructed of other grades of steel.

The A. S. M. E. Unfired Pressure Vessel Code requires unfired pressure vessels which are to be used under the most exacting service conditions to be stress-relieved and others for a limited field of service to be stress-relieved when the shell thickness for a given diameter exceeds a certain figure. Vessels of the latter class are required to be stress-relieved where both the wall thickness is greater than 0.58 in. and the shell diameter less than 20 in., and for all other wall thicknesses and shell diameters where the ratio of the diameter to the cube of the shell thickness is less than 100, and in all cases where the shell thickness is over $1^1/_2$ in.

The A. S. M. E. Unfired Pressure Vessel Code sanctions the use of unfired pressure vessels of the latter class for storing gases other than those of a lethal nature. Where water or other liquid is present in the vessel the pressure for a vessel that may be used without stress-relief is limited to 400 lb. per. sq. in., and the temperature to 300° F. The object of these limitations where the vessels contain liquids is to insure safety for types of vessels where the energy developed in the case of an explosion by the heated liquid has led to disastrous results.

The A. S. M. E. Code is more liberal in its stress-relief requirements than any other Code that I know of; for example, the specifications of the Bureau of Engineering of the U. S. Navy call for stress-relieving all fusion-welded pressure vessels, and the Tentative Requirements of Lloyd's Register of Shipping for Fusion-Welded Vessels Intended for Land Purposes call for heat-treating all vessels subject to internal steam pressures above 50 lb. per sq. in., and other vessels, depending on the service for which the vessels are intended.

One of the objects of the rule given in the A. S. M. E. Boiler Code was to exempt certain vessels from the requirements of stress-relief where it would be impossible to stress-relieve the vessels. The vessels in mind were those built in the field having large diameters, say 30 ft. or more, where it would be impossible to stress-relieve the vessels as a whole and where there would be more flexibility than in a smaller vessel of the same plate thickness.

The rule exempting certain unfired pressure vessels from stress-relief which was finally embodied in the Unfired Pressure Vessel Code was prepared jointly by the AMERICAN WELDING SOCIETY and the Boiler Code Committee. It was published in Mechanical Engineering, the official organ of the American Society of Mechanical Engineers, with a request that criticisms or suggestions be submitted to the Boiler Code Committee. No criticisms or suggestions were received before including the rule in the Unfired Pressure Vessel Code, whereas

* From address on Standards and Codes for Fusion Welding presented at Meeting of Local Sections of AMERICAN WELDING SOCIETY, American Society of Mechanical Engineers and American Society for Metals, Detroit, Mich., April 17, 1935.

† President AMERICAN WELDING SOCIETY.

there has been considerable discussion as to the exactness of the rule since its inclusion and the Boiler Code Committee has been requested to provide a more liberal rule.

Many investigations are in progress and much has been published on the strains and the corresponding stresses due to welding. It has been shown that welding a seam in a pressure vessel may produce elongations in the plate adjacent and at right angles to the weld which will be two or more times as great as that required to produce a stress equal to the yield strength of the material. It has also been shown that the residual strains after the welding, both at right angles and parallel to the weld, may be in the neighborhood of those corresponding to the yield strength of the plate. It is well known that in fusion welding a pressure vessel it will at times rupture due to the strains produced by the welding before the application of the hydrostatic test in the shop, all of which shows that the strains due to the fusion welding are of great magnitude. The question arises as to the effect of these strains should the vessel be placed in service without stress-relief.

There is a feeling on the part of some that if a vessel is placed in service after being subjected to the usual hydrostatic tests that the stresses will gradually diminish due to the creeping of the material and safety will result through the readjustment of the stresses provided the welds are sound and the weld metal of as uniform and as good quality as the plate.

Vessels tested by subjecting them to pulsating pressures have ruptured in the metal of the plate parallel to the weld at lower stresses than correspond to the strength of the material. It has been shown that this action may come through the stresses adjacent to the weld produced by the welding, as these stresses added to the hoop stress produced by the hydrostatic pressure may correspond to or exceed the endurance limit of the material. For certain types of service, therefore, there would seem to be no question but that it is well to stress-relieve all fusion-welded vessels.

A most important feature that must be considered in deciding whether a vessel should be stress-relieved is the chance that the weld will not be as uniform and strong as the parent plate. If portions of the welded joint are not thoroughly fused experience has shown that intermittent stresses due to variations in temperature or pressure will lead to cracks starting at the unfused portions and extending to an extent that may result in danger. Stress raisers of the sort due to imperfections in the weld are something that must be given most serious consideration and in case of a doubt those responsible for the formulation of safety codes naturally lean toward conservative rules.

The results secured in long service are the best measure of safety. It is difficult, however, to formulate rules based on the results secured in service where the art is advancing as rapidly as in the case of fusion welding and where defects may be developed after many years of use. Again, the stresses depend in a great measure on the method used in welding, and many variables are involved. We must not be mislead through the rapid advances that have been made in the last few years into thinking that we know all about fusion welding. As I have said on other occasions, I do not believe we have proceeded over 25 per cent of our way and it is certainly much better to advance carefully rather than to make mistakes for which we may be sorry.

All that I have said bears on fusion-welded pressure vessels. The question naturally arises as to the use of fusion welding in other fields, such as in building, bridge and ship construction, where it would be impossible to stress-relieve most of the joints. Great progress has been made in this type of welding and the record has been exceptionally clean in regard to failures in service. We therefore should not close our minds to providing more liberal rules for the stress-relief of unfired pressure vessels if reliable information is secured which will warrant this being done with safety.

Bursting tests of vessels under hydrostatic pressure made in the ordinary way do not give data on which to base a rule for stress-relief, as the residual stresses due to the welding have little or no effect on the bursting strength, whereas tests under intermittent pressures are especially valuable for the purpose. Such tests were proposed a long time ago by the AMERICAN WELDING SOCIETY and the Boiler Code Committee in working up a series of tests to be made at the Bureau of Standards in Washington. The tests were designated at the time as "breathing tests" in which the vessels were to be subjected to pressures alternating from about zero to $1^1/_2$ times the allowable working pressure. These suggested tests were not made at the Bureau of Standards but The Babcock & Wilcox Company made tests along these lines under the supervision of Professor H. F. Moore. These tests did much in establishing the reliability of fusion welding and they are now regarded as accelerated service tests. Tests of the sort should be sufficiently inclusive as a few tests under a given set of conditions may not solve the problem.

Local stress-relieving, as for example around a nozzle, may set up objectionably high stresses in the shell of a vessel adjacent to or around the part that has been stress-relieved. Where a vessel is stress-relieved in two heats on account of it being longer than can be placed in the stress-relieving furnace, there also may be objectionable stresses should the temperature gradient be too high in the portion between the heated and cooled part of the shell. This feature in stress-relieving a vessel in two heats was provided for in the preparation of the joint API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases, which includes the requirement that the temperature gradient for the part in question shall not exceed 200° F. per foot along the shell.

There are so many features of stress-relief that have not been settled that some users of pressure vessels require all vessels to be stress-relieved when the wall thickness is, say, $^3/_4$ in., or over, even though no stress-relief is demanded by the A. S. M. E. Code.

My own Company has conducted researches at great expense to investigate the strains produced in fusion welding, which we will publish on completion, which convinced us that to secure maximum reliability and safety all vessels should be stress-relieved after welding. In our own practice we usually stress-relieve all vessels even though some are exempted from stress-relief by the A. S. M. E. Code.

We have a lot to learn on this subject and while we should be looking forward to the possibility of using more liberal rules, we should make sure not to proceed unless reliable scientific data and facts show that the revised rules will be safe.

Welded Steel Arch of 166-Foot Span in Czechoslovakia

By FRANTISEK FALTUS†

ONE of the recent notable examples of arc-welded construction in Europe is a steel-arch bridge of 166-ft. span. It is one of the largest welded bridges yet undertaken and is believed to be the first all-welded arch. Located in the Radbusa Valley near Pilsen, Czechoslovakia, the new bridge consists of two two-hinged arch ribs spaced 20 ft. 8 in. apart having a rise of 35 ft. The bridge was designed and built by the Skoda Works of Pilsen.

The arch ribs are built up of $^5/_8$-in. webs, 2 ft. 11 in. deep, and two flange plates, $16^1/_8$ in. wide. The thickness of the flange plates is graduated from $^7/_8$ to $1^1/_2$ in. The arches support the roadway structure consisting of columns, welded columns and cross-girders and rolled longitudinal stringers. The roadway is of reinforced concrete with a granite wearing surface. The total width of the structure is $29^1/_2$ ft. The structural details are shown in Fig. 1 and the design stresses in the accompanying table.

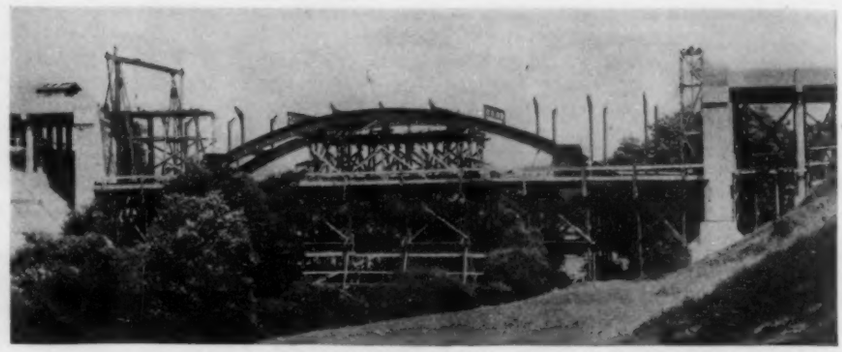


Fig. 2—Erecting the Welded Arch Ribs of a Highway Bridge in Czechoslovakia

† Chief Engineer, Skoda Works, Ltd., Pilsen, Czechoslovakia. Cuts loaned through courtesy of *Engineering News-Record*.

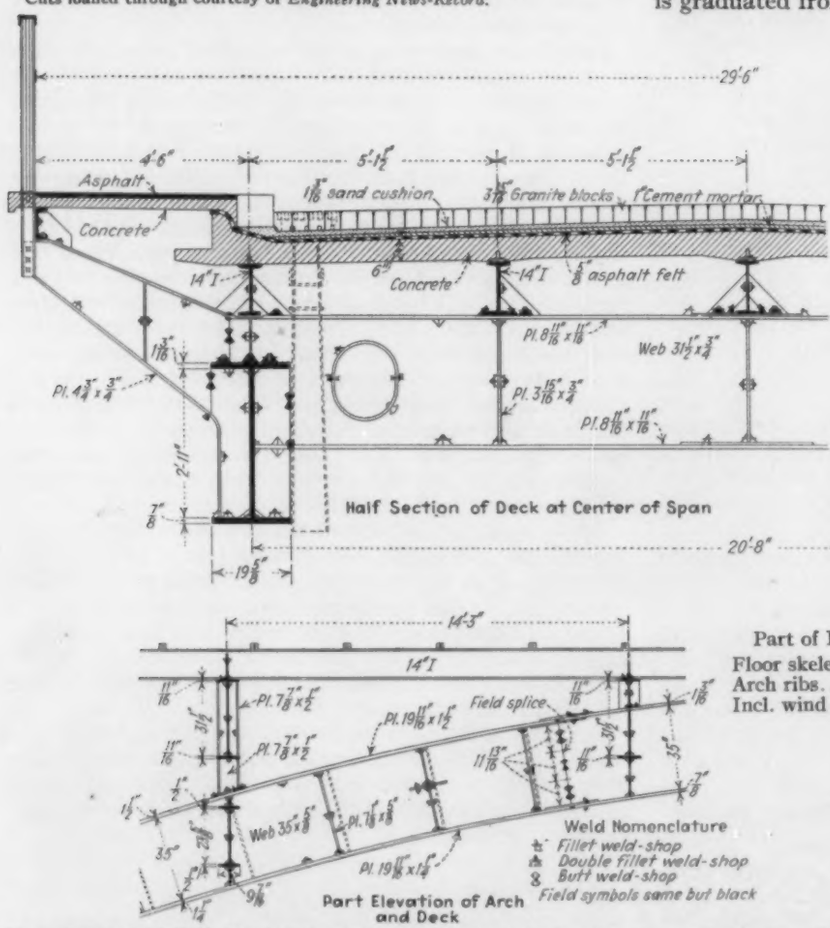


Fig. 1—Details of All-Welded Arch Highway Bridge, Showing a Cross Section of the Deck and an Elevation of the Arch Rib and the Superstructure

The bridge was erected on a timber scaffolding (Fig. 2). Each of the arch ribs was delivered to the site in five sections and assembled on the scaffolding, bolted together and then welded. After the arches had been welded, the roadway structure was erected and welded. All welds were made continuous. About 6 miles of electrodes were consumed, both bare and covered types being used. The bare electrodes that had a core were used on all fillet welds, and all welds were made in a vertical position. The covered electrodes were used for the butt welds, joining the plates of the main arch ribs, where strength and ductility were necessary.

	Lb. per Sq. In.			
Part of Bridge	Base Material	Weld Tension	Weld Compression	Shear
Floor skeleton	12,100	7,800	11,400	7,100
Arch ribs	14,500	9,700	13,800	9,000
Incl. wind stresses	19,200	12,800	17,800	11,400

The weight of the steel structure is 110 tons, of which 47 tons comprise the weight of the arch ribs.

Design Procedure for Converting from Cast Iron to Steel

By E. W. P. SMITH*

WELDED construction permits placing metal to the best advantage and where it is most needed. Every design problem consists of functional specifications and the limiting dimensions for the proposed machine. This problem may be divided into numerous items. The first step is the determination of the most suitable and practical material. Consideration must be given to the selection of the material, its influence on the size, shape, weight, cost of production and operating cost of the proposed machine.

Designers using cast iron are accustomed to its limitations and, therefore, are not always conscious of these same limitations.

One of the most important characteristics of any machine is deflection. We are quite accustomed to thinking of tension and compression stresses but the deflection has to do with the actual operation of the machine and, therefore, is exceedingly important.

It is for the sake of considering this problem that we take an example of a simple beam; a little thought will show that this question of deflection and beam action occurs in practically every machine tool.

The formula for the deflection is $D = \frac{PL^3}{48EI} + \frac{5WL^3}{384EI}$.

The first section of the right-hand member has to do with the deflection due to the concentrated load and the second section has to do with the distributed load of the beam. We are assuming in this case that there is a load concentrated in the center of the beam. Only in the case of extreme accurate calculations do we find it is necessary to use the complete formula. For example, a rectangular beam of cast iron, 3 in. x 10 in., 10 ft. long with a concentrated load of 8000 lb. in the center has a deflection due to this load of 0.096 and the deflection due to the weight of the material 0.007. Now in going from cast iron to steel, the weight of the cast iron beam being greater than that of steel, the deflection of cast iron due to the weight of the beam is, of course, greater than that due to the weight of the corresponding steel beam. Therefore, if we omit this right-hand section, the design of the steel beam will be conservative. In the case mentioned above instead of being 0.007, it will be 0.0028 and, therefore, the steel beam will have less deflection than the cast-iron beam. By omitting this right-hand section of the right-hand member, it simplifies our calculations greatly.

Suppose now that rectangular beam length L with a concentrated load P in the center with a depth d and breadth b, be considered. We know that on the basis of the formula outlined above and our design requirements which say that the deflection must be the same for both cast iron and steel that the following is true:

$$D = \frac{PL^3}{48E_sI_s} = \frac{PL^3}{48E_cI_c}$$

$$E_sI_s = E_c \text{ or } I_c$$

If $E_s = 30{,}000{,}000$, $E_c = 12{,}000{,}000$ and $I_s = \frac{bd^3}{12}$

$$I_c = \frac{bd^3}{12} \times \frac{E_c}{E_s} = \frac{.4bd^3}{12}$$

This is for a straight rectangular beam and on the basis as outlined above it results in a reduction of weight of 60%. Note that this shows the effect on the moment of inertia and does not take any bending or warping into consideration.

The general equation for the bending moment is M equals $\frac{SI}{X}$. M is the bending moment in in.-lb., S = the stress in lb. per sq. in., I the moment of inertia in inches[4] and X the distance from the neutral axis to the most remote fiber in inches. The subscript "t" means tension and c compression and the equation may then be written,

$$M = \frac{S_tI}{X_t} = \frac{S_cI}{X_c}$$

The moment of inertia being the same on both sides of the equation it follows that the ratio of tension to compression is equal to the ratio of respective distances to the neutral axis or $\frac{S_t}{S_c} = \frac{X_t}{X_c}$. Cast iron at 3750 lb. per sq. in. in tension and 22,500 lb. per sq. in. in compression, may be used.

(It is to be noted carefully that these figures may be changed but they will not alter the general discussion, that is, other types of cast iron than the one designated may be used but the discussion is correct.)

The result of these figures is that the ratio of distance to the extreme fiber is 1 to 6. In the same way considering steel at 13,750 lb. per sq. in. for both tension and compression the ratio is 1 to 1.

It is to be noted that the equation $M = \frac{SI}{X}$ will give $\frac{M}{S} = \frac{I}{X}$ which is the section modulus.

The reason we have not considered the section modulus is that I involves the distribution of metal, and X is a dimension involved in that distribution of metal and it is necessary to consider both of these in our welded design. This may seem a bit unusual because the section modulus is usually given in handbooks but it is to be remembered that the sections therein are definite rolled shapes and more or less symmetrical whereas *in welding you put the metal where you need it and no more than you need.* It is necessary to make calculations for these individual items.

Now as to an application of these figures. Assume that we have a beam of cast iron, say, a large operating lever or something of that sort, subjected to bending and that we can convert it into (as far as mathematics

* Consulting Engineer, The Lincoln Electric Company.

is concerned) a simple beam with a load in the center. We have shown that the deflection of the steel beam would be the same as a cast-iron beam, the moment of inertia of the steel beam is 0.4 of the moment of inertia of the cast-iron beam, and it is to be noted that this is minimum moment of inertia.

Referring to the equation: the bending moment M equals $\frac{SI}{X}$ where notation is as given before, several interesting things are evident. If M and S and I are known, X is definitely set. This factor X is one-half the depth of the steel beam. If the dimensions of the space available are such that a depth greater than $2X$ may be utilized then X can be increased by increasing the depth, resulting in a lighter section for the requirements of the design.

It isn't often that there is a rolled section which will meet the particular requirements of the given value of X. If X is increased there is an increase of I which means that deflection has been reduced. This indicates that it is very often possible to decrease the deflection, at the same time decreasing the weight slightly or it means that the design requirements have been changed so that they are more severe than they were assumed to be. Variations of I and X involve mechanical dimension and it is possible that the buckling of the web will be a limiting factor. If we set the dimensions, "M" is set, I is set, then the unit stress at which the beam may be worked is definitely determined. One of the interesting calculations to be made is that if we assume for cast iron 3750 lb. per sq. in. tension and 22,500 for compression and attempt to work it out on a ratio of 1 to 6 as outlined previously, say, on a beam 10 in. deep with $^1/_2$-in. web, the upper flange 1 in. wide, $^1/_2$ in. thick, the lower flange will be found in the neighborhood of $20^1/_2$ in. and $2^1/_2$ in. thick. The absurdity of such a design is evident.

It may be well to call your attention at this time to the casting limitations as part of the governing factors in determining the shape of the cast-iron piece. This is governed very largely by foundry conditions. The fact that the pattern for the mold must be of such design that it may be placed in the sand and removed without disturbing the mold, imposes limitations on the cast iron.

Bear in mind that the ratio which we have been using may be varied by changing the characteristics of the cast iron but the *limitations* imposed by the *casting* still exist due to its inherent characteristics as to *tension stresses* and *compression stresses*, and *also* the *foundry conditions mentioned* above. This is *not* true of steel construction because by the use of welding it is *possible to work every member to the desired limits* and *there are no difficult pattern considerations limiting the designer.*

In order to show this more specifically, suppose we consider definite problems. Space limitations being 6 in. x 10 in. It is evident from the general equations which have been given previously that the mass of metal at a distance from the neutral axis is more effective for stiffness and weight reduction than a mass of metal at the neutral axis. And so, to get what this section would be like, we will assume a theoretical section having two flanges 6 in. wide, 10 in. apart, and the web will be nothing but thin air. Calculations will show that for a bending moment of 184,000 in.-lb. these flanges should be 0.2786 thick. The weight of this section will be 11.30 lb. per ft.; or we can figure this out as 16,208 in.-lb. per lb. of material. Web buckling, of course, will determine the thickness of web and in this case a $^3/_{16}$ web will probably be as thin as it will be advisable to go. Of course, design considerations will dictate the thickness of the web. Inasmuch as there is no standard plate thickness 0.278, we have to use a $^1/_4$-in. plate for the flanges. However, the use of $^3/_{16}$ web will increase the moment of inertia somewhat above that required for the particular design, which in this case happens to be 78.8, to such an extent that the width of the flanges may be reduced 5.5 in. As a result we have an I-shaped beam composed of three plates fused into a single unit by the electric arc and weighing only 15.4 lb. per lin. ft. Starting from this purely theoretical section with the web omitted gives you some idea as to the minimum weight which can be obtained and some idea of the efficiency of the design.

If, now, we take our cast-iron design and having determined the moment of inertia for the steel design we work that out to the best advantage as outlined above, then we can calculate the weight of the cast-iron beam per foot and the weight of the steel beam per foot. This weight per foot is used merely as a convenient figure and for comparative purposes only. If we divide the maximum bending moment in inch-pounds by the weight per foot, we get the number of in.-lb. per lb. per ft. This runs, in the case of cast iron, from about 3500 to 4500 in.-lb. per lb. for the conditions as outlined above. In steel this runs from 5000 to almost 14,000 in.-lb. per lb. of material.

For mobile equipment—such as cranes, trucks, tank trucks, jigs and fixtures, in fact any item in which the portability of the equipment affects the cost of the article, or the use of the equipment—weight efficiency must be considered. For example, a jig or fixture might for a certain weight cost several times what a much heavier jig or fixture would cost but the production from that jig or fixture of lighter weight would be materially greater than that from the heavier one due to the ease of handling and the lesser fatigue of the operator. This same weight efficiency is considered in our present streamline train and light-weight trucks for transporting oil, gasoline, etc.

If, then, we calculate certain costs for a cast-iron beam and for a steel beam, these costs include everything which leads up to the use of the beam in the machine for which it is designed, and we divide the in.-lb. by the cost, we have figures which may be compared to each other, that is, the number of in.-lb. which can be purchased for $1.00 in cast iron, or any other alloy, or casting, and the number of in.-lb. which can be purchased in the fabricated arc-welded steel construction.

Both of these designs have been worked out to meet the same specifications in regard to design requirements.

If the materials are satisfactory, as mentioned previously, then that design or method of construction which results in the lowest cost or the greatest number of in.-lb. purchasable at $1.00 is the design which is selected.

CODE 2

Code for Resistance Welding of Structural Steel in Building Construction

Formulated by

American Welding Society Committee on Building Codes

February 1935

AMERICAN WELDING SOCIETY
33 West 39th Street
New York City

PREFACE

The increasing use in building construction of resistance welded steel members, such as joists, light trusses, stair stringers and similar parts, has developed standardized shop practices for their multiple production. Such building parts shop-fabricated in accordance with these practices have been used throughout the United States for a sufficient length of time to establish their safety in service.

The present code is based on the belief that, in building construction, the application of resistance welding should be restricted to those members which, by reason of their shop fabrication in multiple quantity, can be subjected to definite qualification tests. These tests aim to insure that each member shall develop full strength by requiring that the welded joints of one or more of each product, fabricated by any given setting of a particular welding machine, shall be tested to destruction, and that authoritative records of these tests shall be readily available. Such procedure, it is believed, will lessen the expense and delay of field testing by each local building inspector.

This Code for Resistance Welding of Structural Steel in Building Construction has been so arranged that it may be cited by, or embodied in, existing municipal or other Building Codes. The Committee is prepared to assist in the interpretation of the Code or its applications. Communications should be addressed to the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y.

Sub-Committee
Code for Resistance Welding of Structural Steel
in Building Construction

FRANK BURTON, Chairman	Steel Joist Institute
W. A. HOAR	McClintic-Marshall Corp.
G. A. HUGHES	Truscon Steel Company
H. A. WOOFTER	Swift Electric Welder Co.

Sub-Committee on Scope
Code for Resistance Welding of Structural Steel
in Building Construction

J. L. EDWARDS, Chairman	H. G. BALCOM, Consulting Engineer
GILBERT D. FISH	Consulting Engineer
F. P. MCKIBBEN	Consulting Engineer

The following is the personnel of the Committee on Building Codes as constituted February 1, 1935.

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MALE, MILTON, Secretary	U. S. Steel Corporation
ANDERSON, J. L.	Air Reduction Company
BALCOM, H. G.	Consulting Engineer
BISSELL, A. G.	Consulting Engineer
BISSELL, C. T.	National Board of Fire Underwriters
BURTON, FRANK	Consulting Engineer
DOYLE, E. A.	Linde Air Products Company
EDER, F.	R. W. Hunt Company
ELLIS, A. R.	Pittsburgh Testing Laboratory
FISH, G. D.	Consulting Engineer
FRANKLAND, J. M.	Engineer
HOAR, W. S.	McClintic-Marshall Corporation
HUGHES, G. A.	Truscon Steel Company
LINCOLN, J. C.	The Lincoln Electric Company
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VOM STEEG, JR., E.	General Electric Company
WHITTIER, C. C.	R. W. Hunt Company
WOOFTER, H. A.	Swift Electric Welder Company

(Signed) D. S. JACOBUS, *President*
AMERICAN WELDING SOCIETY

SECTION 1—APPLICATION

1. Resistance welding may be used for the multiple shop fabrication of truss-shaped or beam-shaped members for floors and roofs and for the shop fabrication of steel stringers and sheet steel parts of stairs and other similar members.

SECTION 2—DEFINITIONS

1. Pressure Welding—A process of welding metals in the highly plastic and/or fluid states by the aid of mechanical pressure.
2. Resistance Welding—A pressure welding process wherein the welding heat is obtained by passing an electric current between the contact areas to be welded.
3. Spot Welding—A resistance welding process wherein a weld is made in one or more spots by the localization of the electric current between contact points.
4. Projection Weld—A spot weld wherein projections to localize the heat are provided in one or both of the overlapping parts to be joined.
5. Resistance Butt Welding—A resistance welding process wherein a butt joint is employed.
6. Seam Welding—A resistance welding process wherein the weld is made linearly between and by means of two contact rollers or a contact roller and a contact bar.

SECTION 3—MATERIALS

1. The parts joined shall be steel conforming to the Standard Specifications of the American Society for Testing Materials, Serial Designation A9, or A15 Structural Grade, as amended to date.
2. Surfaces to be welded shall be free from rust, loose scale, dirt and paint, but pickling shall not be required.

SECTION 4—PERMISSIBLE UNIT STRESSES

1. Welds shall be proportioned so that the unit stresses therein shall not exceed 11,300 lb. per sq. in. in shear, or 13,000 lb. per sq. in. in tension. Stresses due to eccentricity of loading, if any, shall be combined with the primary stresses; and the combined unit stresses shall not exceed the values given above.
2. In plates or sheets joined by spot welding, the unit stress at any weld shall not exceed 11,300 lb. per sq. in. In computing this stress, the area used shall be the lesser value of either the actual area of the weld or the product of the thickness of the thinnest piece of metal being welded multiplied by the perimeter of the weld.

SECTION 5—DESIGN

1. Parts to be joined shall be designed to permit sufficient flow of plastic metal to produce proper contact and to extrude any foreign materials, and in such manner that the center lines of electrodes shall pass approximately through the center of the weld.

SECTION 6—MACHINES

1. Resistance welding machines shall be provided with automatic devices for regulating the total available energy and pressure. Machines shall produce uniform welds, uniform in physical properties, and strong enough to provide a factor of safety of at least three in respect to the working load of the weakest member connected.
2. Resistance welding machines should be qualified for the work which they are to produce by actually testing to destruction the welded joints of one or two of each product to be made, the machines to be adjusted until the destructive tests show the machine to be developing the strength factor of safety specified in paragraph 1. Destructive tests of individual joints shall be repeated at least once on every shift and also every time the combination of material being welding is changed. Destructive tests in which the welded joint fails outside the weld shall be accepted as showing the efficiency of the weld, in which case that fact shall be recorded rather than the actual load.

SECTION 7—OPERATORS

1. Operators shall be thoroughly experienced in the use of the welding machines employed. If the operators adjust the machines for making various types of weld they shall correspondingly adjust the machine for making the sample welds. If, for any reason, after the machine has been adjusted and qualified it is found necessary to make further adjustments, a new qualification test shall be made.

SECTION 8—TESTING

1. Contractors for electrical resistance welded parts of buildings shall satisfy the Superintendents of Buildings as to the adequacy and strength of such joints as are resistance welded. When tests are required they shall be performed in accordance with the provisions of Section 6.

New Fixture Cuts Welding Time 60%*

A new type welding fixture with an inclined turntable arrangement for easier handling of circular pieces has been recently perfected by the Harnischfeger Corporation of Milwaukee.

To enable the operator to weld continuously in a downward position, the turntable is equipped with an electrical rotating mechanism with gear shift and variable speed motor control. Speed can be accurately regulated from 3 to 18 inches per minute in either direction at the circumference of the 42" table. Thus, for example, in welding a circular piece,

the operator may hold the rod in a steady position as the work passes beneath it at the desired speed. The turntable can be tilted from one side of the base to the other or held in a horizontal position. Recently, fabricating time on a huge gear was reduced from 32 to 13 hours when sixty-five 5/8" rods were deposited in two hours.

Although primarily designed for handling circular shapes, it also handles other unwieldy pieces. This is an example of how a well designed welding jig may reduce costs with resultant improvement of product.

* From a News Release.

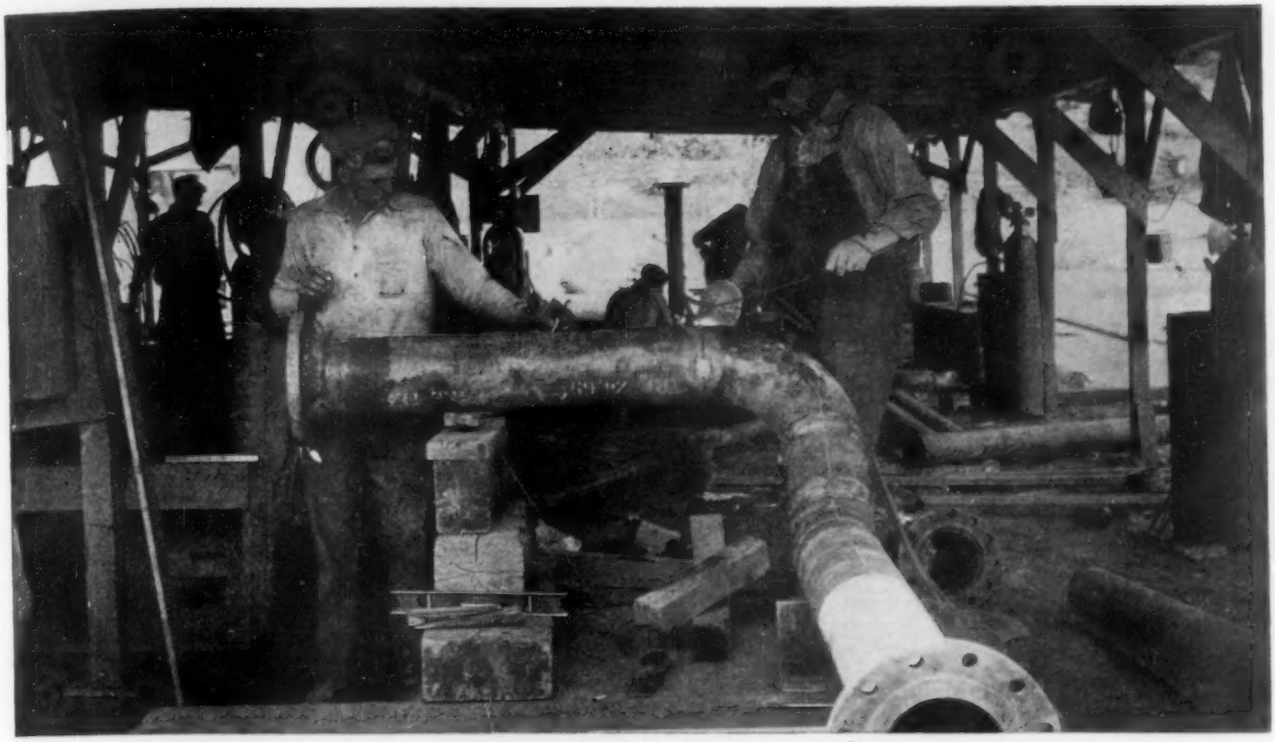


Fig. 1—Shop Fabrication of All Pipe Lines in Good Sized Sections Gives Assurance of Ready Assembly in the Field

Production Methods Used on Welding for Construction Purposes*

By G. E. DEATHERAGE† and J. B. LATTERNER††

IN INDUSTRIAL plants where fluids and gases are processed at high temperatures and pressures, the piping must be designed and constructed with the same care as the pressure vessels which the piping connects. Thus, when piping is fabricated right on the job during construction of a plant, it becomes one of the most important jobs the field forces have to do. If it should be a chemical plant containing a maze of piping, interconnecting practically every piece of equipment in the place, fabrication and erection of the piping becomes by far the most important field operation, worth the unceasing attention of the construction superintendent.

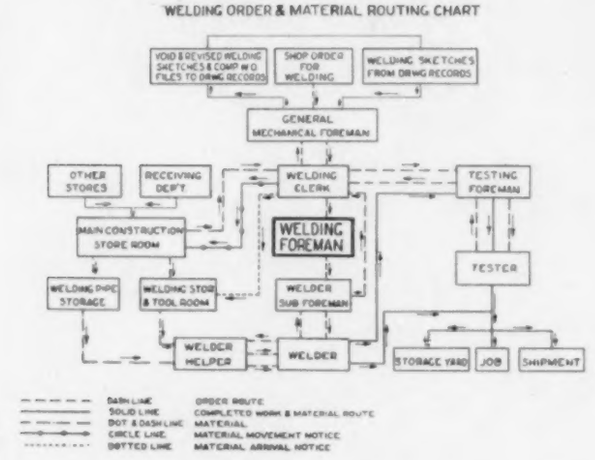
On a well organized construction job, the erection of lines is pushed aggressively because of other work waiting on the piping. A delay in the installation of some one line might interfere with the completion of a half dozen related jobs, and this could not be tolerated. The organization must be such that pipe materials are received, fabricated and the piping erected in accordance with a general construction schedule without jamming any one department with more material or work that can be handled, and without having an over-manned labor crew.

In the construction of various units of a large chemical plant in West Virginia, we early recognized the important part that the piping organization played in the rapid and economical completion of the job. Over a period of years detailed and efficient procedures for pipe fabrication and installation have evolved from our interest in this phase of the work and our constant desire to improve on past practice. In so far as possible, it has been our aim to bring together into a single systematic organization the many miscellaneous activities found on a construction job—to put field work on the same basis common to most all shop production layouts.

In our piping work all joints that possibly can be are welded, hence the piping organization is built entirely around the oxyacetylene process to take the fullest advantage of this versatile method of joining pipe. Welding was adopted originally for piping and pressure vessels for reasons of safety and freedom from maintenance. Cost was a factor little considered. Today, if it should be found necessary to do without welding, we are confident that the cost of piping in place would be greatly increased, and what is even more serious the over-all time for completing a job would be greater. This is because welding has made practicable "made to measure" fabrication and erection of a complete piping job. In the eyes of the construction superintendent this is probably the most important single contribution of weld-

* Read at the 35th Annual Convention, International Acetylene Association, Pittsburgh, November 14, 15, 16, 1934.
† General Supt. of Construction.
†† Chief, Planning Dept., Construction Division, Carbide & Carbon Chemicals Corp.

Beginning with the Shop Order for Welding, the Chart Shows the Route of the Welding Order and Materials through to the Completed Job



DENOTE RECEIVED BY CHECK MARK AND PASS ON TO		WELDER No	TO WELDING FOREMAN DATE
FOREMAN ☐ SUBFOREMAN ☐ WELDER ☐ CHECKER ☐ WELDING CLERK ☐	TESTING FOREMAN ☐ TESTER ☐ TESTING FOREMAN ☐ WELDING CLERK ☐	SUB FOREMAN	FOR JOBS NOT IN SHOP AREA REPORT TO TIME ARRIVED TIME LEFT JOB COMP AND O K TIME LEFT SHOP TIME RETURNED TOTAL TIME
WELDING TIME	TESTING TIME		
START COMPLETED TOTAL	START COMPLETED TOTAL	TESTER No	
DISPOSITION OF COMPLETED WORK FROM			
WELDER TO	TESTER TO	No OF LEAKS	
TESTING FOREMAN ☐ STORAGE YARD ☐ JOB ☐	STORAGE YARD ☐ JOB ☐ SHIPMENT ☐		

Job Routing Chart to Fix Responsibility

ing to construction practices because it greatly simplifies the task of putting field work on a systematic basis. It puts piping installation in the same class with structural steel erection, where members are fabricated to exact dimensions in the shop and are fitted together orderly in the field, in complete coordination with other portions of the construction program.

The plan of operation built around the "made to measure" idea is the logical outcome of experience gained on a number of jobs and the recognition of certain basic facts. Foremost among these is the facility with which a section of a line can be fabricated to exact dimensions by welding—no matter what size the pipe—with assurance that the section will fit into its proper place in the line when delivered on the job. This has been possible in the past with flanged piping, but for the smaller diameter or lower pressure screw coupled lines prefabrication could not be practiced. With welding the entire job is carried out on a production basis using a single method in shop and field in the place of several.

A second factor recognized in applying production methods to piping installation was that the activities of the workman should be confined solely to actual fabrication and erection, leaving the planning to engineers trained in this work. The numerous duties of any one individual under the old state of affairs are reduced to the several for which he is best fitted, with a gratifying decrease in the over-all labor cost.

As the third important step in conducting the job on a production basis, procedure in shop and field is designed to relieve the welder of all duties except that of welding. In this way he may concentrate fully on his work in the interest of weld quality and good production. Since the welds are as important to the completed job as the pipe or welding fittings, it is only to be expected that every care should be taken in making them, yet that their production be facilitated in every way possible. Since the operator is free to do nothing but weld, the amount of production to be expected each day can be gaged fairly accurately. Thus the length of time needed to complete a certain line, with one or more operators at work on it, can be estimated closely and the schedule for the entire job balanced accordingly.

The fourth move, eliminating a constant source of confusion on the job, was considering each line from terminal to terminal as a distinct unit just as though it were a tank or other piece of equipment. Each line is given a definite designation, and all shop drawings, bills of material and work orders refer to this line number. The line is fabricated in easily handled sections in the welding shop and is assembled on the job as a unit, without any stopping until completed.

The fifth factor is placing responsibility for the welding. This is given to one man, the welding foreman, who has under him a number of sub-foremen who actually direct and supervise the welding. The welding foreman is in direct charge of the welding shop where all piping

Fig. 2—Proper Fixtures in the Shop Expedite the Welding

Fig. 3—When the Key Workman in the Organization, the Welder, Has Nothing to Do but Welding, the Quality and Production Will Be Uniformly High

is fabricated before being sent to the job for erection. He is also responsible for welding done on the job, whether for erection, alteration or repair, and he loans operators together with their welding equipment to other foremen for this purpose. Actual erection is in charge of pipe-fitting foremen, both they and the welding foreman coming under a general mechanical foreman.

The last factor has to do with the amount of welding done in shop and field. It was soon recognized that shop welds, being made under more ideal conditions, could be made with less supervision and at lower expense than welds in the field. Consequently a line is broken up into as few units as possible for fabrication, based on the size and weight of sections that can be readily handled, thereby keeping the number of field welds to a minimum.

It is around these six factors then that the plan of operation is laid out: (1) shop fabrication of all lines in good-sized sections, with assurance of ready assembly in the field; (2) giving each individual in the organization a minimum number of duties, to the end that efficiency is increased; (3) giving the key workman in the organization, the welder, nothing to do but welding so that quality and production will be uniformly high; (4) considering the entire piping job as divided into a number of unit lines, each a separate item of equipment; (5) placing the responsibility for all welding, because of its importance, under a welding foreman; (6) and performing the greater part of the welding in the shop where it can be done economically and speedily.

With the welding department uppermost in mind, let us see how the plan operates. First to be considered is the origin of requests for the welding crew to do work. These come from a number of sources. Generally the requests are in the form of standard pipe sketches or shop drawings forwarded to the welding shop from the general mechanical foreman as authority to commence work for new construction. However, they may also be shop orders for doing work not contemplated in the original design, and requests from other departments such as the erection department for operators to do tie-in welding in the field.

No work is done except by authority of some such job order—pipe sketch or shop order—from the general mechanical foreman. It is important to bear in mind that each job order is considered a unit of work—a definite job usually requiring the services of a single welder and his helper. The job may call for the fabrication of a header, or the tack-welding and welding of nine joints required in erecting a line in the field. Each such job is, of course, chargeable to a given line, and therefore no job order concerns more than one line.

Job orders as received are recorded in a "Works File" and a "Works Calendar File" by the welding clerk who is an assistant under the welding foreman. The Works File is simply a blank form in which all needed information about a particular unit of work, the job order, is recorded as the job progresses. The status of any job order at any particular time is thus made available. Provision is made on the form for the number of the line for which the work is being done, the date wanted, the number of the bill of material which was authority for material to be purchased for this particular portion of the job, when the material was received, when the job was started and completed, the number of the

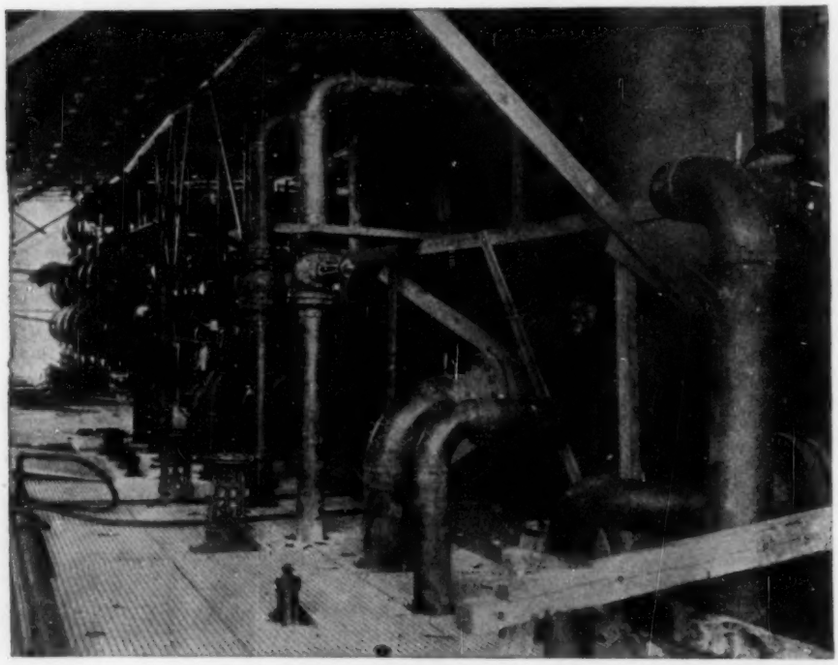


Fig. 4—Welding Was Adopted Originally for Reasons of Safety and Freedom from Maintenance. Economy in Every Type of Pipe Fabrication Is Now a Further Consideration

welder and his foreman, the welding time, results of the tests and disposition of the work upon completion—whether it was placed in storage temporarily or sent direct to the job.

The date wanted is important and will usually be determined by the date the material is scheduled to arrive on the job, this date being supplied by the Bill of Material which is available to the welding clerk along with the job order. If the work happens to be field welding and is not covered by a Bill of Material, the date wanted is secured from the field job order.

The job order is then assigned a date in the Works Calendar File in either of two ways. If the material needed for it has been received or if no material is required, the job is assigned to the "Active" Works Calendar File under the date it is wanted. If the material required is still to come, the job order is listed in the "Pending" Works Calendar File. In this way the work is mapped out a week or more in advance. Should material not arrive in time it can be checked up before the work is actually to start and, if the work scheduled for a certain date is more than the existing organization can take care of, additional workmen are secured or some of the work is advanced to a later date.

The next step is to get the material moving to the welding shop that will be needed there on the following day for the shop jobs scheduled on the calendar. This is attended to by the welding clerk who forwards to the main receiving warehouse the Bills of Material covering the work which is to be done. In this way overcrowding is eliminated in the storeroom at the welding shop because the material is received just a short time before it is due for fabrication.

At the time the welding clerk orders material such as welding fittings moved from the main warehouse, he sends a copy of the Bill of Material to the welding shop storeroom so that provision can be made to handle the material when it arrives. Material from the main warehouse is delivered to the welding shop storeroom in open-top boxes, each box tagged with the work order number and the Bill of Material number. The boxes are arranged in the order of the Bill of Material number so that when needed each can be readily located.

At the start of a day's work, the welding foreman takes the various jobs scheduled to commence on the particular day and assigns them to his various sub-foremen, taking into consideration work not completed the previous day. As explained previously, the authority for a particular job is either a shop drawing or an order to do welding in the field, the one a blue-print and the other a form with the reverse side blank. Before these are given to the sub-foremen, they are rubber stamped on the back with a special form.

Information about the routing of the job is recorded in this form from the time it is assigned until the testing is

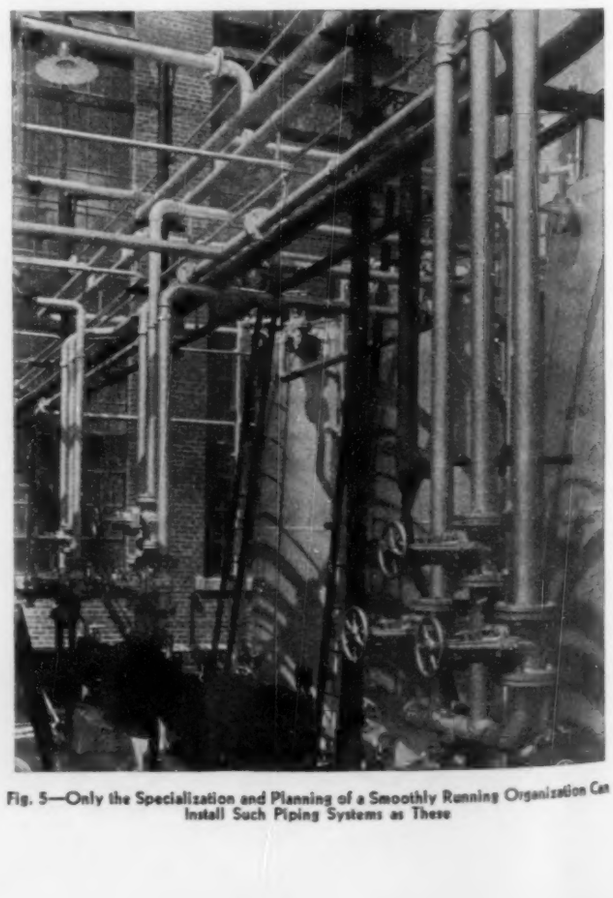


Fig. 5—Only the Specialization and Planning of a Smoothly Running Organization Can Install Such Piping Systems as These

completed and it is sent to the storage yard or to the job. This rubber stamped form also calls for the name of the sub-foreman, the number of the welder and the workman who applies the test, the date given to the welding foreman, the welding time, testing time and final disposition of the work. For welding jobs not in the shop area, space is provided on the form for the name of the field foreman the welder is to report to and the time he was away from the shop.

The job order with the form stamped on the back is passed from workman to workman as the job passes through the shop and the stage of the work at any particular time can be readily learned.

The welding sub-foremen assign the jobs to various welders under them in sufficient time for the welders' helpers to get the pipe and welding fittings necessary from the storage area, eliminating any break in the flow of work. When a job order is presented at the welding shop storeroom for the welding fittings and flanges required, a list of the pipe called for on the order is immediately forwarded to the pipe yard so that the exact lengths needed can be made ready. The welder's helper is given a duplicate copy of the order to the pipe yard so that he can pick up the pipe as needed.

A record is kept of welding time and all welds are stamped with the welder's assigned number to fix responsibility for the welding and time consumed. Each section of a line fabricated in the shop is also marked with the correct order number, number of the line and a number identifying the particular section.

The work is tested in accordance with its service requirements, after which it is held temporarily in a storage area or delivered to the job, depending on how soon the particular line is to be erected.

For welding jobs outside the shop area the welder assigned to the work takes the order and gets his equipment and welding supplies to the job with the cooperation of the welding clerk who arranges in advance for the necessary transportation. The welder does the work specified, stamps the welds with his number, and returns to the shop. If the sub-foreman believes it necessary, he accompanies the welder to the job to see that the work gets under way and is performed in a satisfactory manner.

The field foreman to whom the welder reports for work records the time of the welder's arrival and departure on the back of the job order and gives the welder any instructions he may need in the performance of the work. He also notes whether the work was satisfactory and complete, and gives the job order to the welder to be returned to his sub-foreman.

The job order is finally returned to the welding clerk with complete information in the form stamped on the back. He transfers as much of the information on the back of the job order to the work file as necessary, and passes the job order along to the general mechanical foreman which is notification to him that the work has been completed.

These records required on welding work in the shop and field are relatively simple to keep and definitely fix responsibility for each step of the work. No orders or requests are given verbally in following this procedure and in the memorandum system followed all work of whatever type performed, whether trucking, testing or welding, is chargeable to some job. In this way cost accounting is also greatly simplified.

The care used in routing pipe and welding fittings on the job to eliminate holdups on account of material shortage has already been mentioned. Similar care is exercised in the handling of welding equipment and supplies. To each welder is issued a set of tool checks, one of which he gives up to the toolroom clerk for a kit of tools, another for a welding outfit and the others for any special equipment he may need.

Greater Economy in the Fabrication of Unusual Pipe Sections Is Permitted by Shop Fabrication

Welding supplies such as rods, flux, etc., are charged to the proper line number. It is relatively easy to estimate the amount required for the job since the number and size of the welds can be taken from the job orders. Each job order, of course, refers to a particular line. To make sure that there is never a shortage of welding supplies, material is reordered just as soon as the inventory gets down to a minimum figure determined upon.

Various daily and weekly reports are required of the welding foreman and his men in order that the construction superintendent may know about the progress and quality of the welding. One of these is a daily report on the welders covering the estimated welding time for the previous day compared to actual welding time. Another is a weekly report on welders covering estimated welding time compared to actual welding time and in addition the number of hours worked to date on pipe welding per leak for each welder.

A weekly report on the amount of work going through the welding shop calls for an estimate of the number of hours of uncompleted work held over from the previous week, estimated hours of work scheduled for the current week, the probable actual number of working hours and the balance which will have to be carried over to the next week. In addition, the hours scheduled for the next week are reported, from which the number of welders required can be estimated. A welding service record is maintained for each welder so that if he should leave the company, but be considered for reemployment at a future date, his past record would give specific indication of his ability.

In building up a smoothly running organization we have had one paramount thought in mind: that the American factory industrial system of specialization and planning has produced really astounding results in the manufacture of quality products at low cost, and that the same idea can be applied in large degree to field construction practice.

Field construction activities in the past were left almost altogether in the hands of the foreman. He personally supervised listing, material needed, securing it from the storehouse, fabricating it and putting it in place. The construction foreman for years was the kingpin about which all activities revolved. This was the condition requiring change.

Discussion: "Standard Connections for Welding" by Van Rensselaer P. Saxe*

By ANTHONY S. COOMBS†

THE writer of the article which is discussed in the following remarks stresses the desirability of structural welding standards, and recommends that these standards be sponsored by the AMERICAN WELDING SOCIETY.

There certainly is a need for coordination along these lines, but it would seem to be doubtful if it is possible or desirable to have welded connection details standardized nearly as completely as for riveted work. The inherent advantage of flexibility in the use of welding, its adaptability under varying conditions, is an argument against too rigid standardization.

But whether or not it is agreed that types of welding connections be standardized, there seems to be a great need for an "approved practice" in design. Anyone who has made any study of the design of welded structural details is confronted with this same difficulty, and, as is stated by Mr. Saxe, few engineers have the opportunity for research or the facilities to make comparative tests. They must of necessity rely on their own reasoning and methods of analysis, or be guided by published data based on the deductions of others.

There have been numerous publications pertaining to the design of structural details, and the analysis of each may conform to the principles of structural mechanics, yet a comparison of the results obtained will often show considerable variation. It is the assumption on which the design is based that accounts for the difference in results. Due to the scarcity of test data, assumptions have to be made. As soon as research has supplied enough information on the behavior of full-size welded joints, many of these suppositions can be eliminated.

At present the structural welding engineer is handicapped by this lack of knowledge, and he is obliged to design conservatively, to be on the safe side. In consequence, welding does not compare as favorably as it might with riveted work.

Take for example the familiar riveted beam connection, consisting of a pair of side-connection angles. In a riveted design the strength of the connection to the beam web is determined by the value of the rivets either in shear or bearing, as occasioned by the vertical shear due to the end reaction. Ordinarily no account is taken of the eccentricity of the connection. From experience we are satisfied that this method of design is adequate.

But with a similar welded connection there is not yet sufficient test data to justify designing the welds on the basis of vertical shear only, and it is customary to add a certain amount of welding to take care of the moment due to eccentricity. No doubt the connection should be designed for both vertical shear and moment, but even so there appears to be a lack of agreement among engineers as to how the connection should be computed. Generally each connection angle is welded to the beam web with a vertical weld along the toe of the angle, and short horizontal welds along the top and bottom cut edges of the angle. (By vertical and horizontal welds, reference is based on the position of the welds when the beam is in place in the structure.) One method of design is to consider that the vertical shear is uniformly distributed over the total length of weld, and that the moment due to eccentricity is opposed by a resisting moment determined from the polar moment of inertia of the welds, the maximum resultant stress due to shear and moment not being allowed to exceed the working stress for the weld metal.

Another method is to assume that the vertical shear is resisted by the vertical welds, and that the moment is resisted by the top and bottom horizontal welds, these welds acting as a couple, with the vertical distance between them as an arm.

In still another solution of this same problem the welds at the supporting surface are designed to resist a moment due to eccentricity, together with a direct shear from the reaction. In this case the welds to the beam web are computed on the basis of shear from end reaction only.

The design of welded seat angles has been open to the same criticism, but the recent tests made under the auspices of the American Bureau of Welding at Lehigh University, under the supervision of Prof. Inge Lyse and Mr. Norman G. Schreiner, will no doubt result in definite recommendations covering design procedure for this type of connection.

Another point which needs clarifying is the effective size of a fillet laid against a rolled edge, such as the toe of an angle. Although all angles are rolled with the edges rounded, some designers disregard the effect of the rounded welding edge of the angle, and use fillet welds of the same nominal size as the thickness of the angle. Others increase the thickness of the angle by at least $^1/_{16}$ in., or more often $^1/_8$ in., in order to obtain a square edge along the angle, which will approximate the nominal size of the fillet, or else the fillet is computed at a reduced stress.

Other instances could be quoted which indicate a difference of opinion as to the proper method of design procedure.

The Structural Steel Committee of the American Bureau of Welding has been doing notable work and has made valuable contributions leading to a more thorough understanding of the nature and behavior of welds and welded connections. This program will doubtless be continued and extended to cover other types of welded connections as time and opportunity permit.

The lack of accord in the methods of design is disconcerting, and it is quite possible that it may arouse a feeling of uncertainty in the minds of building officials who are not familiar with welded work, and at the same time welding is being penalized by the fact that the most conservative method of design is often selected, to be on the safe side.

It would be a great help to structural engineers, if, as soon as possible, the results and recommendations of the Structural Steel Committee be incorporated in a Code for Structural Welded Design. A few definite design recommendations have already been written into the Code for Fusion Welding and Gas Cutting in Building Construction, but there is still a great need for a code or handbook covering design problems in more detail, and published under the authority of the AMERICAN WELDING SOCIETY.

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* JOURNAL OF THE AMERICAN WELDING SOCIETY, Jan. 1935, p. 15.
† Engineer, The Whitney Engineering Co., 100 Arlington St., Boston, Mass.

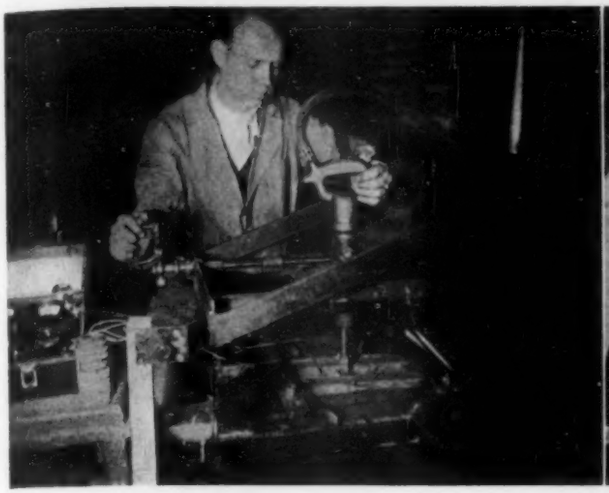


Fig. 1—Peening Machine

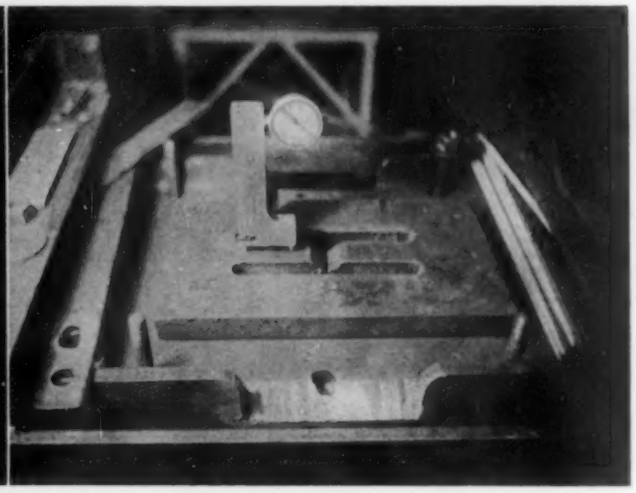


Fig. 3—Taking Strain Gage Readings

Effect of Peening on Physical Properties of Welds and Stress Relief*

By PROF. O. M. HARRELSON†

KNOWING the action of the different elements when alloyed with iron, there will be a considerable change in the structure and physical properties of material when welded due to the sudden changes in temperatures. The deposited metal is different from that of the parent metal in that it is cast rather than rolled. The rolled steel has improved properties by having received a mechanical refining treatment while passing through the rolls in a plastic form. This is done by the destroying of the pre-existing coarse crystallization and producing a grain which is much smaller, and more uniform throughout the entire mass. In the case of deposited metal, it is not possible to obtain these advantages. We also have to give consideration to non-metallic or oxidized impurities and gas impurities such as nitrogen, which the metal will absorb from the atmosphere forming atomic nitrogen which combines with the iron forming FeN_4. These impurities are very detrimental to the ductile properties of the weld.

The machine used for peening was designed and built as shown in Fig. 1 which was used to control the effective blow of the air hammer by the use of an air reservoir with a capacity of a 100 cu. ft. connected between the air line and the regulator. The air hammer was placed in the carriage holder of the machine and clamped with special set screws to prevent its moving in the holder, then connected to the regulator.

The carriage of the machine was designed to move in any direction at a constant speed and fixed so it could not move from the effect of the blow of the hammer. The material to be welded was clamped firmly to the bed of the machine to prevent any loss of the effective blow from the hammer through vibration. The hammer was then calibrated to find the effective blow using the following formula:

$$F_2 = \frac{PA(S\,S_2)}{S_2}$$

Where P = lb./sq. in. of air on piston

A = area of piston

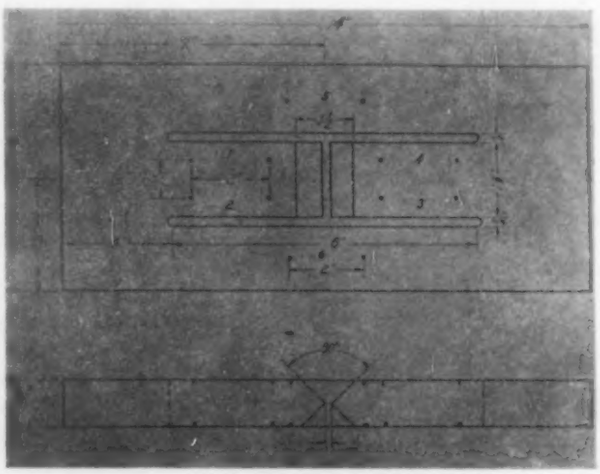


Fig. 2—Preparation of Plates

* Paper to be presented at Fall Meeting of the American Welding Society, October 1–5, 1934. This report is a contribution to the Fundamental Research Committee of the American Bureau of Welding.

† Georgia School of Technology.

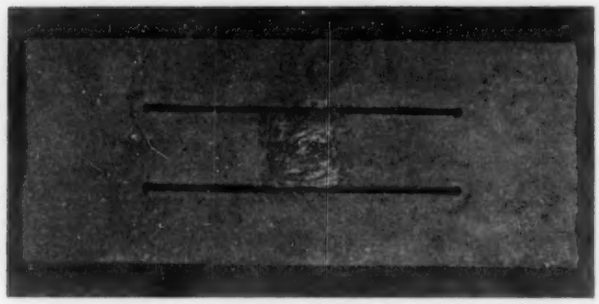


Fig. 4—Completed Weld

S = stroke of piston in ft.

S_2 = penetration of chisel

$$F_2 = \frac{70(0.8861 \times 0.38)}{0.00086} = 33{,}500 \text{ lb.}$$

S_2 was obtained by the use of a specially made surface gage.

Various pressures were used on the air hammer while peening the welds, and from the test data it was proved that the more effective pressure was 70 lb.

The following material was used in the test:

1. Structural steel plates $1^1/_4$ x 6 x 14 in.
2. Electrodes used:

(*a*) $^5/_{32}$-in. bare, using 145 amp. and 18 volts, full load.

(*b*) $^5/_{32}$-in. light-coated, using 140 amp. and 20 volts, full load.

(*c*) $^5/_{32}$-in. heavy-coated, using 135 amp. and 25 volts, full load.

The method used for preparing materials follows:

By the use of the oxyacetylene cutting torch, the plates were prepared as shown in Fig. 2. After the center bars were formed a special jig and punch was used to obtain the strain gage holes as also shown in Fig. 2. When the preparation of the plates was finished they were stored in a room with the Berry strain gage and allowed to age for about eight weeks before welding so as to allow the strains due to cutting temperatures to localize themselves at room temperature.

Then the zero strain gage readings were recorded and the plate placed in the machine and clamped.

The plate was welded so as to distribute equally the heat liberated in the arc stream and the arc terminals on both sides of the double "V" joint of center bar so as to maintain as nearly as possible a uniform stress in the plate due to expansion and contraction on both sides of center bar. When the weld was completed the temperature was taken and recorded, plate removed from clamps (as shown in Figs. 3 and 4) and strain gage readings A_h and B_h taken. Then the plate was allowed to remain in the same room for about 24 hrs., allowing the plate to attain room temperature. Then the strain gage readings were taken again and recorded (in data) as A_c and B_c. This procedure was repeated identically for each test plate run.

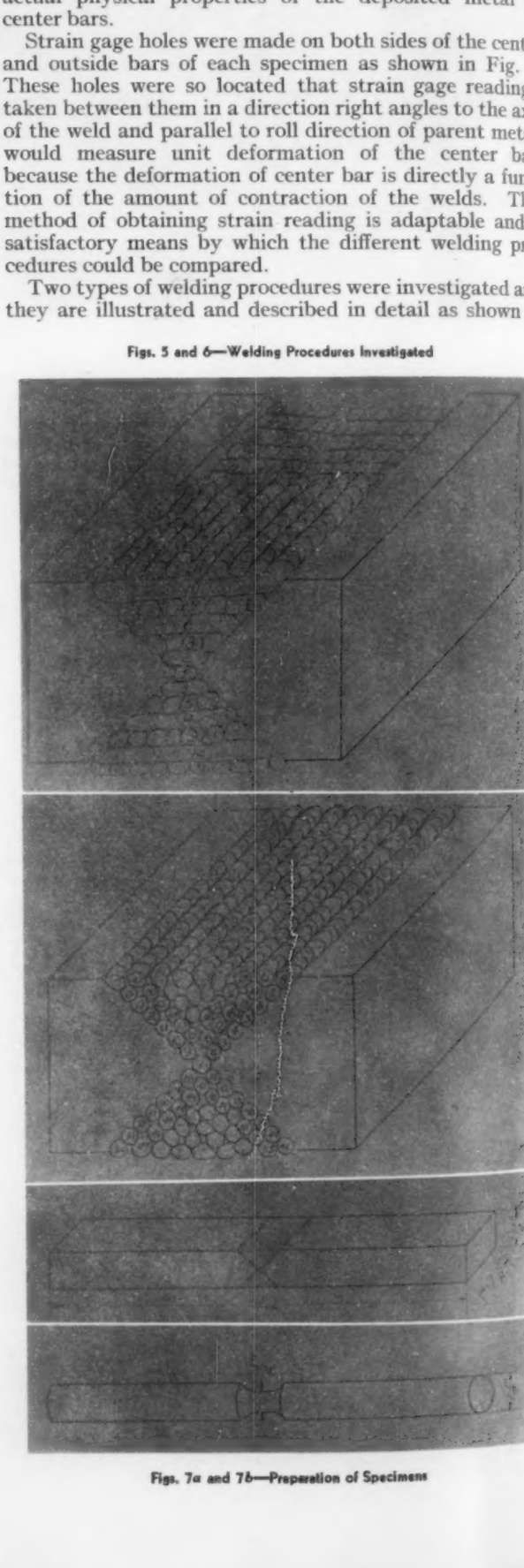
The test plates used in the investigation consisted of $1^1/_4$ x 6 x 14-in. hot-rolled steel plates prepared as stated. This type of joint was used because of its simplicity, its high degree of rigidity and its adaptability for obtaining the strain gage reading with a fair degree of accuracy.

The 90-deg. double V type joint was used for the purpose of obtaining a more uniform distribution of the strains and a large area of deposited metal. The large area of deposited metal made it possible to determine the actual physical properties of the deposited metal of center bars.

Strain gage holes were made on both sides of the center and outside bars of each specimen as shown in Fig. 2. These holes were so located that strain gage readings, taken between them in a direction right angles to the axis of the weld and parallel to roll direction of parent metal, would measure unit deformation of the center bar, because the deformation of center bar is directly a function of the amount of contraction of the welds. This method of obtaining strain reading is adaptable and a satisfactory means by which the different welding procedures could be compared.

Two types of welding procedures were investigated and they are illustrated and described in detail as shown in

Figs. 5 and 6—Welding Procedures Investigated



Figs. 7*a* and 7*b*—Preparation of Specimens

Table 1—Physical Test on Welded Bars

Spec. No.	Tensile Strength, Lb./Sq. In.	Elastic Limit, Lb./Sq. In.	Per Cent Reduction in Area	Per Cent Elongation	Rockwell Hardness, B Scale	Type Peened	Electrodes, Non-Peened
1	51,500	31,200	15.5	13.8 in 0.56″	72		5/32″ A
2	49,000	36,000	14.2	14.2 in 0.57″	72.5		"
3	49,150	28,200	14	11.2 in 0.72″	72		"
4	43,600	34,500	10	10 in 0.70″	69		"
5	45,500	34,600	10	5 in 0.80″	75.5		"
6	52,900	33,700	20.3	12.5 in 0.80″	70.5	5/32″ A—Bare	
7	51,500	33,800	20.4	14.7 in 0.68″	67.8	"	
8	52,900	36,300	23.5	16.7 in 0.90″	67.8	"	
9	54,000	38,000	22	15.9 in 0.59″	74	"	
10	56,600	37,600	21.9	15.5 in 0.79″	66.2	"	
11	55,850	38,000	23.5	17.8 in 0.82″	70.6	"	
12	54,150	34,600	22.6	20 in 1.00″	67.5	B—Light coated	
13	74,400	44,500	45.3	33 in 0.87″	68.5	5/32″ C—Heavy coated	
14	57,500	44,800	43.2	35.8 in 0.73″	71		5/32″ C
15	52,800	32,600	20	14.5 in 0.74″	67.8	1/8″ C	
16	53,000	36,500	21	12.5 in 0.80″	60		1/8″ C
17	74,200	41,000	46.5	32.6 in 0.75″	70.6	5/32″ C	
18	69,800	40,000	40	29 in 0.65″	72		5/32″ C
19	58,200	36,350	25.4	20 in 0.90″	65.5	5/32″ A	
20	44,300	32,700	19.6	8.3 in 0.72″	67.5		5/32″ A
21	54,500	35,600	19.5	20.5 in 0.88″	63.5	5/32″ A	
22	49,000	31,000	19.4	18.1 in 0.66″	67		
23	69,500	43,800	41.5	28.5 in 1.04″	62		5/32″ B
24	76,400	44,100	47.6	32.2 in 0.96″	60	5/32″ B	
25	70,000	43,600	29.2	29.2 in 1.05″	60.5		5/32″ C
26	53,850	38,500	19.4	17 in 1.05″	64	5/32″ A	
27	49,600	29,500	74.5	38 in 7″	49	Base Metal	
28	49,000	29,600	71.5	31.6 in 8″	49	Base Metal	

Figs. 5 and 6. The different procedure was in the method of depositing the weld metal and the application of peening.

The deposited metal was equally deposited in the upper and lower V's as shown, in an effort to eliminate bending stresses in center bar as much as possible.

The test procedure consisted of running several tests non-cleaned and non-peened, taking strain gage reading on each specimen with a Berry strain gage before and after welding, while weld was hot and after cooling to room temperature. Also the same procedure was carried out as follows:

(*a*) Cleaning and peening each deposited layer.

(*b*) Cleaning each deposited layer and peening every other.

(*c*) Cleaning each deposited layer and peening every third.

(*d*) Cleaning each deposited layer and peening twice in each V of joint.

(*e*) Recording temperature before and after peening all welds and taking strain gage reading as stated above. The effective blow of the peening hammer was controlled by putting the hammer in a fixed position and regulating the air pressure as previously explained. Various pressures were used in order to determine from results what pressure is most effective on the peening of welds. The pressures used were 50, 60, 70 and 75 lb. per sq. in. Results obtained show that an average effective pressure of 70 lb. per sq. in. gives the most effective results on relieving residual strains and stresses in welded metals.

All welds were made controlling welding, current, welding voltage, temperature and peening with the purpose in view of making each weld identical.

When all test specimens were welded and data recorded, an oxyacetylene-cutting torch was used to cut the center bars out of plate as shown in Fig. 7*a*. The test bars were then allowed to age at room temperature for about four weeks, then machined, and turned down in the weld proper as shown in Fig. 7*b* for running the physical tests as shown in Tables 1 and 2.

The reason for cutting the test bars down in the weld proper was to insure obtaining the results of the physical properties of the welded metal and not parent metal.

Then specimens were cut from the weld proper of test bars for microphotographic study. The structures of the deposited metal in an electric arc weld is, to a certain extent, that of cast steel with the loose coarse crystalline structure. Therefore, the physical properties are similar to those of cast metal. Because through the continuous heat treatment the weld receives through the process of welding, physical properties are improved over that of cast metal.

In fact it is found that the deposited metals are relatively lower in ductility than in strength. This has been proved from the microscopic examination of fracture and cut sections from welded areas, also the physical tests that the specimens have been subjected to.

The microphotographs shown herewith show that the metals are unsound, in that they are contaminated with non-metallic inclusions, and lack of union and strong bond between some of the crystals. This offers the reason for the loss of ductility in welded metals. On the other hand, the increase in strength is no doubt due to the inherent method of welding.

These microphotographs also reveal many large black needles in the ferrite grains which is evidence that crystals of nitride of iron are present, which make the crystals more brittle than the crystals they are imbedded in.

This will again help to increase strength and decrease ductility, although it has been proved in this investigation that the physical properties can be improved by controlled procedure of welding and peening which will offset some of the above-named faults.

Figure 8 shows welded area of test bar No. 4 as listed in Table 1, non-peened. This photomicrograph shows a cross section of welded area. The black areas are slag and cavities due to improper welding and cleaning of each deposited layer. The structure is an aggregate of ferrite and sorbito pearlite. The black needles as seen in the white areas are nitride of iron, known as

Fig. 8—150×

Fig. 9a—200×

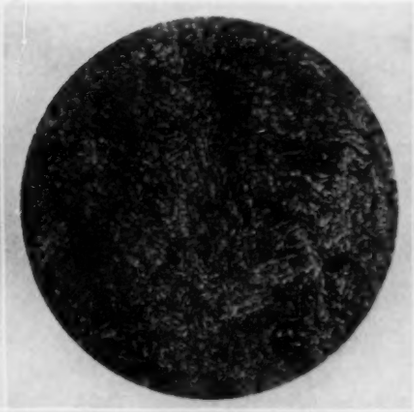


Fig. 9b—200×

Fig. 10—150×

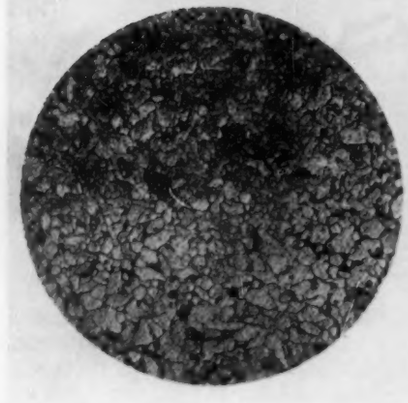


Fig. 11a—200×

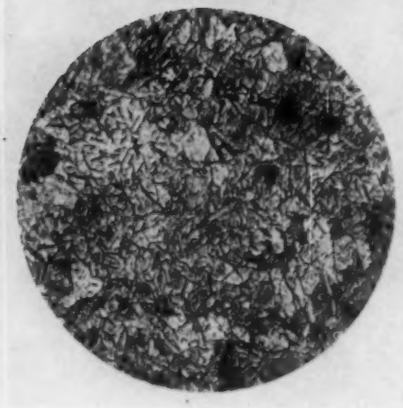


Fig. 11b—150×

All Specimens Nital Etched

Table 2

Spec. No.	Types of Electrodes	Welding Procedure	Air Pressure, Lb./Sq. In. on Hammer	Average Strain Gage Readings Sides A & B, Hot	Sides A & B, Cold	$e = \frac{\text{Gage Reading} \times 0.0002}{2}$ Sides A & B, Hot	Sides A & B, Cold
1	5/32" A	Cross and Horizontal		41.25	20.85	0.00412	0.00208
2	"	Weave, Non-Peened		28.12	20.85	0.00381	0.00285
3	"	" "		37.90	19.27	0.00379	0.00192
4	"	Vertical Layer Weave		35.22	18.87	0.00352	0.00188
5	"	Non-Peened		39.87	18.62	0.00398	0.00186
6	"	Cross and Horizontal	50	23.62	17.62	0.00236	0.00176
7	"	Weave Peened	70	22.25	10.50	0.00222	0.00105
8	"	" "	50	20.00	10.25	0.0020	0.00102
9	"	Vert. Layer Peened	70	21.62	9.62	0.00216	0.000962
10	"	" " "	70	25.87	12.25	0.00258	0.00122
11	5/32" B	Cross and Horiz. N.-P.		23.12	12.50	0.00231	0.00125
12	"	Cross and Horiz. P.	70	17.75	9.12	0.00177	0.00091
13	5/32" C	Cross and Horiz. P.	70	30.50	15.87	0.00305	0.00158
14	"	Cross and Horiz. N.-P.		40.87	19.57	0.00408	0.00197
15	1/8" C	Cross and Horiz. N.-P.		24.87	14.00	0.002487	0.0014
16	"	Cross and Horiz. P.	70	19.87	10.00	0.00198	0.0010
17	5/32" C	Cross and Horiz. Weave P.	70	22.25	9.62	0.00222	0.000962
18	"	Cross and Horiz. N.-P.		38.87	19.12	0.00388	0.00191
19	5/32" B	Cross and Horiz. Weave P.	70	21.25	11.50	0.00212	0.00115
20	"	Cross and Horiz. Weave N.-P.		28.87	12.25	0.00288	0.00122
23	5/32" A	Cross and Horiz. Weave N.-P.		44.50	21.43	0.00445	0.002143

135 amperes, 18–20 volts were used on all 5/32" (A) bare electrodes.
130 amperes, 25 volts were used on all 5/32" (C) heavy-coated electrodes.
130 amperes, 25 volts were used on all 5/32" (C) heavy-coated electrodes.
130 amperes, 18–20 volts were used on all 1/8" (C) heavy-coated electrodes.
135 amperes, 18–20 volts were used on all 5/32 (B) light-coated electrodes.

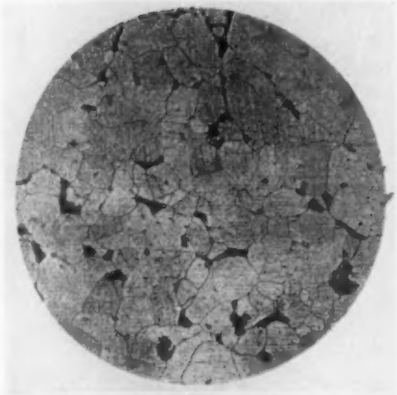


Fig. 12—150×. Nital Etch

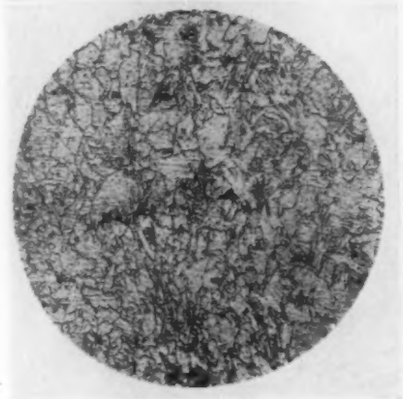


Fig. 13—150×. Nital Etch

nitride needles. This structure relates why the physical properties are as low as shown in Table 1.

Figure 9*a* shows outer layer of cross section of deposited metal in test bar No. 7, which was peened. Structure is an aggregate of ferrite and granulated pearlite or sorbite. We also have present a eutectoid of iron and iron nitride.

Figure 9*b* shows the inner layer of the deposited metal near the junction of base and deposits. Structure shows a uniform aggregate of ferrite and pearlite. The white areas are ferrite and the dark areas are pearlite, with the exception of little round black spots that are seen in the white area which are oxides. The black needles that are seen in the white areas are nitrides. These microphotographs indicate good physical properties which check with results given in Table 1.

Figure 10 shows a cross section of the deposited and base metal of test bar No. 17, peened. The upper section is deposited metal which is a fine aggregate of ferrite and sorbito pearlite. The lower section shows the base metal. Structure is a fine aggregate of pearlite and ferrite. Under high magnification the white area in the weld section reveals that some nitriding took place, also some non-metallic inclusions were present. The dark areas in both sections show scorbutic or laminated pearlite. The welded junction is of very good quality, showing perfect arrangement of grains.

This structure reveals ideal physical properties. (See results of specimens in Table 1.)

Figure 11*a* shows an outer cross section of deposited metal from heavy-coated electrodes on a low-carbon steel, non-peened. Structure is a uniform aggregate of ferrite, nitride of iron and sorbito pearlite. In the outer layers of the welded area, nitriding took place in that nitride needles are present in the ferrite grains.

Figure 11*b* shows a cross section of the welded junction between the base and deposited metal of a heavy-coated electrode, it being noted that this microphotograph is of the same specimen as that of Fig. 11*a*.

The upper section is the deposited metal which is a fine structure of ferrite and sorbito pearlite. In that nitriding took place in the outer layers of deposited metal as shown in 11*a*, there is no reason why nitrides should not be present in the inner layers and doubtless constitute part of the dark pearlite-like areas which are composed of a eutectoid of iron and iron nitrides.

The little dark particles are non-metallic inclusions. The lower section is the base metal which is an aggregate of ferrite and pearlite. These structures reveal good physical properties but, due to nitriding that took place, the ductility was slightly reduced as will be seen in Table 1.

Figure 12 shows the structure of the cross section of test bar No. 22 made of the original metal. Structure is ferrite (white areas) and pearlite (dark areas). The percentage of dark areas indicates that the steel is about 0.10–0.15 per cent carbon. The structure indicates a very ductile material. (See Specimen 22 in Table 1.)

(It will be noted that in Figs. 8, 9*a* and 9*b* the micro structures were taken from bare electrode deposits and that in Figs. 10, 11*a* and 11*b* the micro structures were taken from heavy-coated deposits. Figure 12 is a microphotograph taken from the original base metal.)

The photomicrograph in Fig. 12 shows outside cross section of welded area made with heavy-coated electrodes on low-carbon steel.

The structure is an aggregate of ferrite and pearlite, holding in solid solution some impurities such as iron nitrides and iron oxides. The nitrides are shown in the ferrite grains as black needles; also in the form of a eutectoid of Fe and FeN_4 which is shown as a dark pearlitic substance. The iron oxides are present in the form of dark, round spots.

The distorted grain structure is due to two things:

1. Peening below the (AX) transformation point.
2. Heat evolution, causing recrystallization.

The deformation resulting from cold working (Fig. 12) has caused an orientation of the ferrite and pearlite particles to be elongated in a non-uniform direction, but it will be noticed that the ferrite areas remain structureless, and indicates that it has the same crystalline orientation throughout.

The evolution of heat observed at the (AX) temperature necessarily indicates a sudden change of internal energy which probably results from a relief of internal strains, this relief, in turn, causing recrystallization, hence, the coincidence of the two phenomena. Bearing in mind that the more severe the cold working, the lower the temperature of recrystallization, it should be expected that after severe deformation the (AX) point will occur at a lower temperature. V. N. Krivobok[1] has found the above results to be true from his investigation on samples of hypo-eutectoid steels and Armco iron while cold worked and then heated, the evolution of heat being observed in the vicinity of 650° C.

For a check of data obtained from test on the $1^1/_4$ x 6 x 14-in. plates as shown in Tables 1 and 2, four other plates were prepared as shown in Fig. 14. The gage holes as shown on center and side bars were drilled with a No. 56 drill and reamed with a special reamer. The $^1/_4$-in. holes between the gage holes were drilled $^1/_2$ in. deep and filled half full of mercury. Then the hot junctions of chromel-alumel thermocouples were submerged in the mercury and connected through a special

[1] Sauveur, "Metallography and Heat Treating of Iron and Steel," Chapter XVII.

switch to the Leeds & Northrup Potentiometer as shown in Fig. 16.

The mercury and special switch made it possible to obtain temperatures at these points with a fair degree of accuracy while welding. Strains were taken with a Berry strain gage using a 2-in. gage length as was used in the other test. These gage readings and temperature readings were taken on both sides of the plates.

Two of these welds were made with bare electrodes, in one of which every other deposited layer of metal was peened while welding. The other two were welded with coated electrodes using reverse polarity, one being peened as stated above.

When welds were completed they were allowed to cool to room temperature and strain gage readings taken. Then the center bar was cut through the center of the weld and gage readings taken again. Results are shown in Table 3.

In order to obtain information as to whether the residual stresses caused by welding are the same in thin plates as in thick plates, 6 x 14 x $^1/_4$-in. plate was selected and prepared as shown in Fig. 15. The same procedure of welding and peening as was done on the thicker plate was carried out, with the exception of welding and recording temperatures at points 1, 2, 3 and 4 being done only on one side. Strain gage readings were taken at points 1, 2, 3, 4 and *C* on both sides with a Berry strain gage using 2-in. gage length. In addition to these strain readings a 10-in. Whittemore strain gage reading was taken at points 5, 6 and 7 on both sides of the plate.

Fig. 14—Preparation of Check Plates

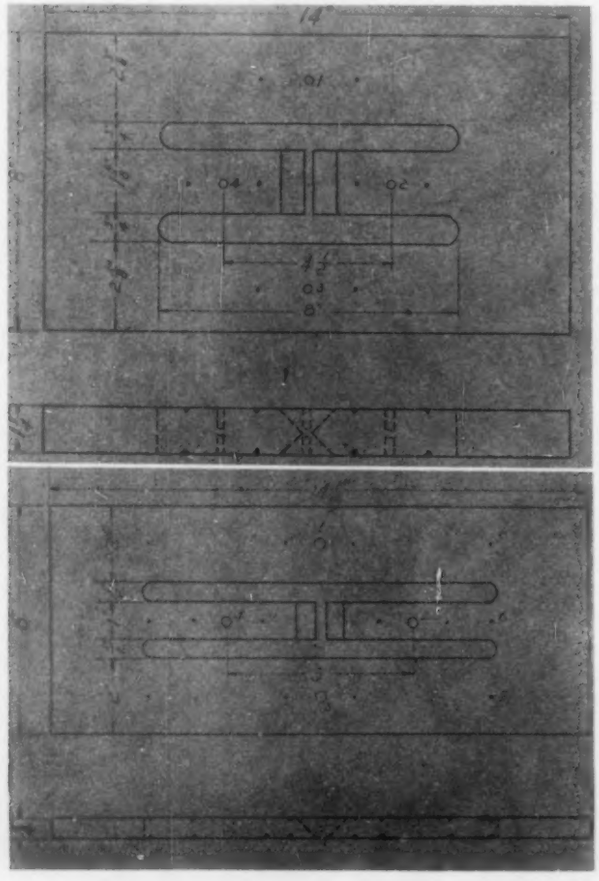


Fig. 15—Preparation of Thin Plates

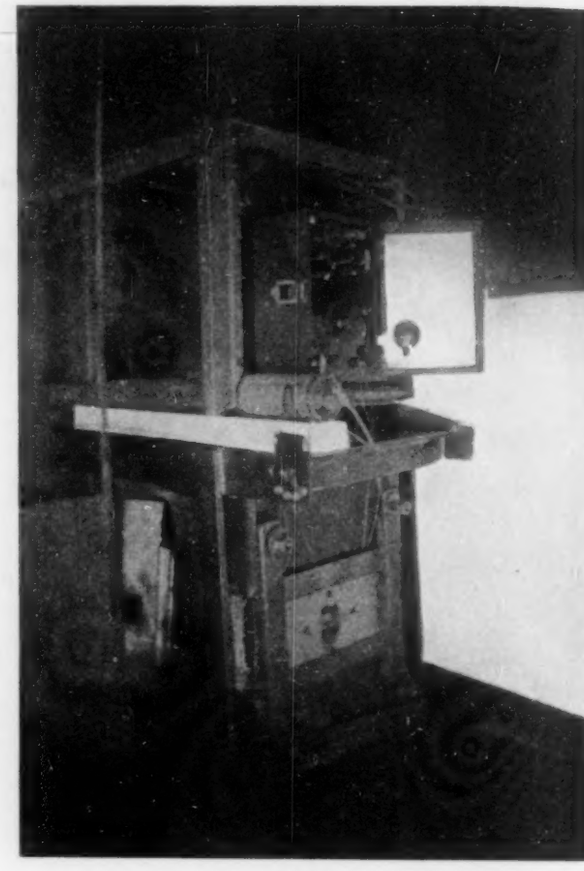


Fig. 16

Four bars were prepared as stated above, in two of which the welds on center bars were made in 60° V double bevel joint with a $^1/_4$-in. opening at the bottom. One of the welds in each case was peened as was done in the thicker plates.

After the welds were made and allowed to cool down to room temperature, the gage readings were taken and center bars cut through the center of the welds and the strain gage reading again recorded.

The No. 1 weld cracked after cooling, therefore the results were discarded. The results of the other bars are recorded as shown in Table 3.

Discussion of Results

Where peening of the weld is done, it is possible that certain portions of the welds could have been peened more than others. This would affect the distribution of stresses causing a variation of gage readings. Although being able to control the effective blow by the use of a special peening machine, as has been previously explained, it is reasonable to believe this has been cut to a minimum.

The inherent method of welding means the deposition of small globules of metal which form on the end of the cathode and fall into the anode puddle or crater, which in turn forms the thin layer of deposited metal. This process of deposition causes an uneven distribution of stresses because the progressive layers of this deposition causes progressive heating and cooling which causes a non-uniform stress distribution. This would cause variation in gage reading.

Even though there should have been considerable variation in strain readings due to inaccuracy of methods used in obtaining the readings, it would not have greatly

Table 3—Calculation Showing Locked-up Stresses in Rigid Frames Caused by Expansion and Contraction

The strain gage reading taken before and after welding center bar in frames (or plates) as shown in Fig. 14 furnished necessary data for computing the residual stresses resulting from the shrinkage of deposited metal.

$S = Ee$
S = Stress in lb./sq. in.
E = Modulus of elasticity
e = Measured unit elongation in inches

Spec. No.	e Center Bar	S Center Bar	e Outside Bar	S Outside Bar	Peened	Non-Peened	Thickness of Plates in Inches
1	0.00208	62,400				"	1 1/4
2	0.00285	75,500				"	"
3	0.00192	57,600				"	"
4	0.00188	56,400				"	"
5	0.00186	55,800				"	"
6	0.00176	52,800			"		"
7	0.00005	31,500			"		"
8	0.00102	30,600			"		"
9	0.000962	27,960			"		"
10	0.00122	36,600			"		"
11	0.00125	37,500				"	"
12	0.0009	27,300			"		"
13	0.00158	47,400			"		"
14	0.00197	59,100				"	"
15	0.0014	42,000				"	"
16	0.0010	30,000			"		"
17	0.000962	28,860			"		"
18	0.00191	47,300				"	"
19	0.00115	34,500			"		"
20	0.00122	36,600				"	"
23	0.00214	64,200				"	"

Spec. No.	e Center Bar	S Center Bar	e Outside Bar	S Outside Bar	Peened	Non-Peened	Thickness of Plate in Inches
The following specimens were run for a check on previous data obtained.							
5	0.00315	94,500	0.00308	92,400		"	1 1/4
6	0.00325	96,500	0.0033	99,000		"	"
7	0.0025	61,500	0.00128	38,400	"		"
8	0.00257	76,000	0.00168	49,400	"		"
The following specimens were run for a comparison of data on 1 1/4- to 1/2-in. plate:							
2	0.00222	66,600	0.0022	66,000		"	"
3	0.00212	63,600	0.0022	66,000	"		"
4	0.00195	58,500	0.0020	60,000	"		"

Spec. No.	e Center Bar Cut	S Center Bar Cut	e Outside Bar after Center Bar Was Cut	S Outside Bar after Center Bar Was Cut	Stress Released on Center Bar after Cut
The following specimens were run for a check on previous data obtained:					
5	0.000775	22,350	0.00020	6000	72,250
6	0.0005	15,000	0.0001	3000	81,500
7	0.000475	13,250	0.0001	3000	48,000
8	0.0005	15,000	0.0001	3000	61,000
The following specimens were run for comparison of data on 1 1/4- to 1/2-in. plate:					
2	0 000475	13,250	0.000	0	53,350
3	0.00035	10,500	0.000	0	53,500
4	0.0003	9,000	0.000	0	49,500

affected the amount of stress set up by expansion and contraction caused by the cooling deposited metal. A second series of test specimens was run to check these results and find out if different thicknesses of plates would affect the results. These data repeated the same condition in each.

Then a further investigation was brought about to determine if it were possible for deposited metal to shrink (or contract) enough in a butt weld to cause such stresses. Investigation proves that shrinkage was much higher than expected. This can be easily understood from the study of the effect of steel cooling from the molten condition passing through the AGSE area iron carbon equilibrium diagram which is composed of a solid solution of finely dispersed carbon in gamma iron, known as austenite.

On further slow cooling the solution crosses the broken line GSE on side GS. At this point the alpha ferrite separates out and forms a mixture of alpha and gamma iron. Then on further cooling this mixture passes through another transition point at the (LSK) eutectoid line, which means that the solution has changed to an aggregate of alpha ferrite and cementite. During the passage of the metal through this transition point, there has been a complete change in crystallization of metal during which the crystals in reforming set up a tremendous amount of stress in the center bar of the plate, caused by the contraction of the individual crystals.

In making a study of the structures by microscopic examinations of sections cut from the test specimens, it was proved that peening improved the quality of welds by eliminating some of the impurities such as oxides, etc., also helping to form a uniform structure by forming a closer and more perfect bond between crystals.

The study also shows that strain had been set up in the outside deposited layers because the crystals had been distorted. This in itself accounts for the amount of stresses that were set up in the center bars of the test specimens.

Conclusions

The study of the summary of all test data obtained has revealed the fact that peening of welds relieves stresses and improves structures and all physical properties of the metals.

If it were possible for the percentage of shrinkage of deposited metal to be reduced, the problem of high stresses would be solved. With this in view, a thorough investigation could be made to find some method of alloying the electrode metal to aid in the reduction of shrinkage.

It is the writer's purpose to make it definitely clear that the high stresses that were obtained in the investigation do not occur except in very rigid type of structures.

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CATALOGUE

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WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

New Officers Elected

President

J. J. Crowe, Air Reduction Sales Company, Jersey City, N. J.

Senior Vice-President

E. R. Fish, The Hartford Steam Boiler Inspection & Insurance Company, Hartford, Conn.

Divisional Vice-Presidents

Pacific Coast Division: Turner C. Smith, General Petroleum Corp. of California, Los Angeles, Calif.

Southern Division: E. E. Dillman, Wyatt Metal & Boiler Works, Dallas, Texas.

Directors

C. A. Adams, Harvard Engineering School, Cambridge, Mass.
H. M. Hobart, General Electric Company, Schenectady, N. Y.
F. T. Llewellyn, United States Steel Corp., New York, N. Y.
D. S. Jacobus, Babcock & Wilcox Company, New York, N. Y.
G. D. Spackman, Lukenweld, Inc., Coatesville, Pa.
H. L. R. Whitney, M. W. Kellogg Company, New York, N. Y.

At the Board of Directors' meeting the following appointments were made:

Executive Committee

J. J. Crowe, Chairman; Air Reduction Sales Company.
C. W. Bryan, Jr., Federal Shipbuilding & Dry Dock Co.
J. H. Deppeler, Metal & Thermit Corporation.
R. S. Donald, Thomson Gibb Electric Welding Company.
E. H. Ewertz, Consulting Engineer.
F. M. Farmer, Electrical Testing Laboratory.
E. R. Fish, Hartford Steam Boiler Inspection & Insurance Co.
D. S. Jacobus, Babcock & Wilcox Company.
M. M. Kelly, Secretary.
C. A. McCune, Magnaflux Corporation.
H. S. Smith, Union Carbide Company.
E. Vom Steeg, General Electric Company.
A. Weymouth, Post & McCord.
H. L. R. Whitney, M. W. Kellogg Company.

Treasurer

C. A. McCune, Magnaflux Corp.

Secretary and Assistant Treasurer

M. M. Kelly

Our President

Mr. John J. Crowe, elected president of the AMERICAN WELDING SOCIETY at their annual meeting held at the Hotel Pennsylvania in New York on April 25th, brings to that office not only a keen appreciation of the problems confronting the Society, gained through his service as senior vice-president since 1933, but also a wealth of experience in association work. From 1920 to 1921 and from 1923 to 1924, he served as Chairman of the Philadelphia Chapter of the American Society for Metals, and from 1921 to 1922 as a Director of the American Society for Metals. He served the New York Chapter of this society as chairman from 1932 to 1933, and was a director of the AMERICAN WELDING SOCIETY for the ten years from 1924 to 1934.

Mr. Crowe's interest in metallurgy began shortly after graduation from high

school in Washington, D. C., when he went to work at the Bureau of Standards as an apprentice. His first assignment, the testing of thermometers and the making of heat measurements, under the direction of the late Dr. C. W. Waidner, formed a fitting foundation for his work in the Pyrometer Division which was under the direction of the late Dr. G. K. Burgess. While serving as an apprentice, Mr. Crowe continued his education by attending evening classes in George Washington University.

In those days, little was known about the practical application of pyrometers and the need for research work along this line was continually being brought to the attention of the Bureau through requests for advice and assistance from manufacturers of steel. There was no department or division of the Bureau organized to cover the field of metallurgy so Dr. Burgess assumed the responsibility by taking this work into the Heat Division where it was subsequently organized as a separate division with a personnel of two, Dr. G. K. Burgess and Mr. J. J. Crowe. It has since grown to such an extent that it requires a large sized building to house the metallurgical activities introduced by Dr. Burgess and Mr. Crowe.

While associated with the Bureau of Standards, Mr. Crowe cooperated with Dr. Burgess and Mr. Waidner in the publication of a number of papers on thermometry, pyrometry and metallurgy; the title of some of these papers being:

1. Location of the A C_2 Point in Pure Iron
2. Finishing Temperatures of Rails
3. Observation on Ocean Temperatures in the Vicinity of Icebergs.

The first paper listed is used as a reference in practically all text-books. The Titanic disaster served as an inspiration for the paper on ocean temperatures in the vicinity of icebergs.

By 1915, Mr. Crowe had been advanced to the position of associate physicist in charge of a section in the Bureau. During that year he was "loaned" to the U. S. Navy Department for the purpose of rendering metallurgical assistance in the development of anchor chain at the Boston Navy Yard. Up to this time the large chain used on the anchors carried by the battleships was forged and welded by manual labor. The development consisted largely in replacing the hand-hammer operation by power-hammer operation and the proper heat treatment of the finished chain to obtain the best possible results under the severe service to which this chain is subjected. Work at the Boston Navy Yard was not limited to the development of anchor chains but included supervision of the heat treatment of all of the forgings made in the forge shop and castings made in the yard foundry and the establishment of a physical testing and metallurgical laboratory at this yard. This laboratory was the first metallurgical laboratory established in any of the Navy Yards.

Instead of returning to the Bureau of Standards Mr. Crowe accepted an appointment as Physical Metallurgist with the U. S. Navy Department and was transferred from the Boston Navy Yard to the Philadelphia Navy Yard. Here he established another metallurgical laboratory and assisted in the establishment of similar laboratories at both the New York and Norfolk Navy Yards. The Naval Aircraft Factory at the Philadelphia Navy Yard was just beginning production and there were many metallurgical problems which arose. In addition to finding the solutions to these problems, he was called upon to lend his assistance to laying out the large workshop used for the manufacture and heat treatment of heavy forgings for the

Navy ships then under construction in the yard.

It was at the Philadelphia Navy Yard that Mr. Crowe had his first real contact with the practical application of fusion welding and cutting by the oxyacetylene process. By applying the oxygen cutting process in the Forge Shop great savings were made in the cost of producing the large forgings and fusion welding was used to advantage not only there but in the foundry.

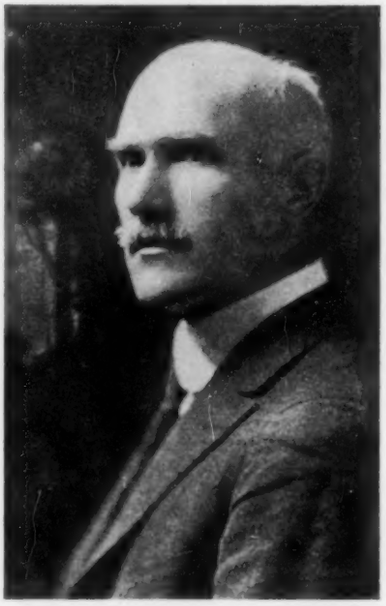
In 1921 Temple University was persuaded that they should establish a course in metallurgy. This was done and Mr. Crowe was given the position of director of this department and served in that capacity until 1924. During his association with the U. S. Navy and Temple University, he acted as consulting engineer in many important developments.

In 1924 he left Philadelphia to accept the position which he now holds of Engineer in charge of Apparatus Research and Development for the Air Reduction Company with laboratories located in Jersey City. Since being with the Air Reduction Company, Mr. Crowe's activities with the American Society for Metals, American Institute of Mining & Metallurgical Engineers, American Society for Testing Materials have been continued and have been increased to include the AMERICAN WELDING SOCIETY, the Compressed Gas Manufacturers Association and the International Acetylene Association. In addition to taking a number of patents applying to oxyacetylene equipment he has published a number of papers on the use of oxygen and oxyacetylene equipment, the most noteworthy papers being "Economy Through the Use of High Purity Oxygen," published in the Journal of the AMERICAN WELDING SOCIETY in 1925 and "Effect of Tip Sizes and Pressures upon Economy of Cutting," published in the Transactions of the International Acetylene Association for 1928.

E. R. Fish
Senior Vice-President, A. W. S.

Mr. E. R. Fish graduated from the St. Louis Manual Training School and later from Washington University with the degree of Mechanical Engineer. After a year or two of miscellaneous work with the Washington University Testing Laboratory, the General Electric Company, Street Railway Department and the Lewis Locomotive Valve Gear Company, he joined the Engineering Department of the Heine Boiler Company. After service in practically all departments of the company Mr. Fish became Secretary and later Vice-President. He had charge of the manufacturing plant for a number of years and after the absorption of the Heine Boiler Company by the Combustion Engineering Corporation, became consultant in boiler matters to the latter company. During this time Mr. Fish acquired wide experience in the design, manufacture and operation of boilers of all kinds and sizes.

Five years ago he accepted the position as Chief Engineer of the Boiler Division of the Hartford Steam Boiler Inspection and Insurance Company. Mr. Fish is an active member of the American Society of Mechanical Engineers having served a term as Councilor and Vice-President of the Society and has long been a member of



its Boiler Code Committee and Chairman of the Unfired Pressure Vessel Sub-Committee. Mr. Fish is also a member of the main committee of the A. S. M. E. on Power Test Codes, of whose Sub-Committee on Steam Generating Units he is Chairman.

He has long been interested in welding, particularly the last five years, during which time methods of testing and of determining what constitutes good welds and how good welding can be assured has been a particular study. He is past-president of the American Boiler Manufacturers Association, the Engineers Club of St. Louis, Alumnae Association of Washington University and other similar organizations.

H. Le Roy Whitney
Made Member of Board of Directors, A. W. S.

Mr. H. Le Roy Whitney was born in New York City on February 4, 1884. His father, a steel man, built some of the first elevated railroads in New York City and some of the first structural buildings. He was a partner in the Carnegie Steel Company until its absorption by the U. S. Steel Corporation. Mr. Whitney graduated from the Sheffield Scientific School of Yale University in 1905 with the degree of Ph.B. He was a member of the Yale Varsity crew during the years 1904 and 1905.

After about a year in a lead and zinc mine in Indian territory, he joined the M. W. Kellogg Company and has been associated with them ever since. He is now a Director of the company, as well as Sales Engineer and Chief Engineer of the Fabricated Products Division.

He has served as Chairman of the Republican National Committee for Morris County and during the war was connected with the 1st New York Field Artillery and the 302nd Field Artillery in France. He was a Major in the Reserve Corps of Cavalry.

Fall Meeting Program

The Meetings and Papers Committee will shortly meet to consider the program for the Fall Meeting. Every member of the AMERICAN WELDING SOCIETY is afforded an opportunity to make suggestions for this fall meeting program. If you have a paper which you would like to present or wish to suggest a paper, you are respectfully requested to send in your suggestions at once to Mr. W. Spraragen, Secretary, Meetings and Papers Committee, American Welding Society, 33 West 39th Street, New York, N. Y. All suggestions should be in Mr. Spraragen's hands before June 6th.

Codes

During the past few months a number of important codes have been formulated and issued by the AMERICAN WELDING SOCIETY. In nearly every instance these were made available in the JOURNAL of the Society. They are also available in separate form at the prices indicated below.

- 1934 Edition of Code for Fusion Welding and Gas Cutting in Building Construction, Code 1—Part A—Structural Steel—25¢
- Tentative Code for Fusion Welding and Flame Cutting in Machinery Construction—25¢
- Code for Resistance Welding of Structural Steel in Building Construction—10¢
- Welding or Cutting Certain Types of Containers Which Have Held Combustibles—15¢
- A.W.S. Marine Code for Welding and Gas Cutting—Part D—Rules for the Fusion Welding of Hulls and Hull Parts—15¢
- Investigations of Welded Seat Angle Connections—25¢

In addition to the above the AMERICAN WELDING SOCIETY has available the following reports:

- Report of Structural Steel Welding Committee—50¢
- The Practical Design of Welded Steel Structures, by H. M. Priest—25¢
- Erecting Steel Buildings and Strengthening Steel Bridges by Welding, by F. P. McKibben—25¢
- Report on Welding and Cutting Nomenclature, Definitions and Symbols—25¢
- Tentative Specifications for Filler Metal for Use in Fusion Welding—25¢
- Report of Committee on Welded Rail Joints—$1.00
- Training Course for Oxyacetylene Welders—25¢
- Training Course for Electric Arc Welders—25¢
- Fundamentals of Oxyacetylene Welding—50¢

Fundamentals of Thermit Welding—50¢
Fundamentals of Resistance Welding—25¢

1934 Bound Volume

Bound volumes of the JOURNAL of the Society for the year 1934 are available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Also contains Subject and Authors' Index. Price $5.00 plus postage to members; $6.50 to non-members.

Rules for the Fusion Welding of Gravity Tanks, Tank Risers and Towers

These rules are supplementary to the Regulations of the National Board of Fire Underwriters for the Construction and Installation of Tanks, Gravity and Pressure, Towers, etc. They have been prepared by a joint committee of the AMERICAN WELDING SOCIETY and the International Acetylene Association at the instance of the National Board of Fire Underwriters' Advisory Engineering Council. Pursuant to the action of the Council, these rules are recommended by the National Board of Fire Underwriters to fire insurance rating and inspection boards and bureaus and service organizations as a basis for the acceptance of welded construction.

These rules are available at 25¢ per copy.

National Coordinated Program for Welding Research

The welding industry has been particularly active in research. This research effort received an initial impetus during the war and has been maintained with practically no let-up ever since. Industrial research in the welding field has been supplemented by university and governmental research. Cooperative welding research has been under the general guidance of the American Bureau of Welding.

For some time many interested in the progress of the art have felt the need for greater coordination of research in the welding field and for increasing the effectiveness of research workers generally by making available in usable form the knowledge recorded in the literature.

Engineering Foundation has in the past made grants to aid two or three welding research projects but has proposed that the technical societies and industries concerned cooperate in the development of a coordinated and comprehensive research program for the welding art.

Under the joint sponsorship of the American Institute of Electrical Engineers and the AMERICAN WELDING SOCIETY an application was made to Engineering Foundation for a grant of $5000 for the first year to initiate such a program. An important conference was held on April 22nd of representatives of those interested and a resolution was unanimously adopted endorsing the proposal for a coordinated, comprehensive welding research program including all process and expressing appreciation of the generous offer of the initial grant of $5000 made by Engineering Foundation. A research committee has been appointed by Engineering Foundation to supervise this work, consisting of the following: C. A. Adams, Chairman; W. A. Spraragen, Secretary; J. H. Critchett, J. J. Crowe, H. M. Hobart, D. S. Jacobus, G. F. Jenks and F. T. Llewellyn.

Handbook

For some time the AMERICAN WELDING SOCIETY has had under consideration a handbook on welding. Providing such a handbook can be financed it is proposed to secure the cooperation of some sixty outstanding experts in the welding field to prepare special chapters. An Editorial Committee consisting of D. S. Jacobus, Chairman; C. A. Adams, F. T. Llewellyn and C. W. Obert has been appointed to survey the field and to explore the possibilities of financing such a book.

The plan proposed calls for the underwriting of the handbook by companies that will place advance orders for copies of the book at $4.00 each. Those companies that believe in the need for such a book should communicate at once with Dr. Jacobus, care of the AMERICAN WELDING SOCIETY, indicating the number of copies that the company will be willing to pledge themselves for. It is proposed that copies of the handbook would be made available without charge to members in good standing of the AMERICAN WELDING SOCIETY. After the book is published it is proposed to sell copies of the books to non-members at $5.00 each.

No actual work will be started on the book until the necessary funds needed for the completion of the book are responsibly underwritten.

Hollup Corp. Appointed Westinghouse Distributor on Arc Welders for Steam Railroads

To better serve the interest of the steam railroad industry, the arc welding manufacturing and technical facilities of Westinghouse have been combined with the Hollup Corporation Sales Service. This brings to United States and Canadian Railroads high standards of efficient welding service.

Westinghouse is a pioneer in the development and application of arc welding. The Hollup Corporation for 21 years has been a leader in the development of the highest grade of welding supplies and in the solution of arc welding problems.

Milwaukee Section Organized

The first organization meeting of the Milwaukee Section of the AMERICAN WELDING SOCIETY was held on Thursday, April 18th, at the Milwaukee School of Engineering. The following officers were elected:

Chairman—Otto Voss, Allis-Chalmers Mfg. Co.
Vice-Chairman—K. L. Hansen, Harnischfeger Corp.
Secretary-Treasurer—J. J. Chyle, A. O. Smith Corp.

Baltimore Section Formed

The necessary steps have been taken to form a Maryland Section of the AMERICAN WELDING SOCIETY with headquarters in the City of Baltimore. At the Board of Directors' meeting held in New York on April 25th, a charter was granted for the formation of this Section.

Mr. H. N. Boetcher of the Consolidated Gas, Electric Light & Power Company was elected Chairman, and Mr. A. B. Cromer was elected Secretary-Treasurer.

Russian Welding Society

The following Cablegram was received by the AMERICAN WELDING SOCIETY:

"THE MEMBERS OF THE SCIENTIFIC TECHNICAL SOCIETY OF WELDING ENGINEERS OF USSR AT THEIR MEETING DEVOTED TO RESISTANCE WELDING UNANIMOUSLY VOTED MANY THANKS TO THE BOARD AND MEMBERS OF THE AWS FOR THEIR ASSISTANCE IN EXCHANGING EXPERIENCE BETWEEN AMERICAN AND SOVIET WELDING ENGINEERS."

SECTION ACTIVITIES

BOSTON

The following officers were elected by the Boston Section for the year 1935–36:

Chairman—H. N. Ewertz, Austin Hastings Co.
Vice-Chairman—J. P. Walsted, Bethlehem Shipbuilding Corp.
Secretary-Treasurer—P. N. Rugg, Edison Electric Illuminating Co.
Directors for 2 years—C. W. Babcock, Westinghouse Elec. & Mfg. Co.; J. H. Zimmerman, Massachusetts Institute of Technology; H. R. Bullock, Massachusetts Institute of Technology
Trustee—A. L. Combs, Linde Air Products Company
Director to the National Society—L. F. Jackson, Retiring Chairman

CHICAGO

A "Railroad Welding" meeting was held by the Chicago Section on April 26th. Mr. J. B. Tinnon, Sales Manager, Metal & Thermit Corporation, addressed the meeting on "Butt Welding of Railroad Tracks"; Mr. R. G. Mason, Foreman of Welding, A. T. & S. F. R.R., spoke on "Railroad Reclamation by Welding," and Mr. S. E. Tracy, C.B. & Q. R.R., presented an address on "Railroad Welding." The meeting was preceded by a dinner.

CLEVELAND

The Cleveland Section held a series of talks by local men outstanding in the welding industry for their meeting held April 10th at the Cleveland Engineering Society. The speakers and subjects covered by each were as follows:

H. O. Westendarp, Jr., Welding Specialist, General Electric Company—A.C. Welding and Its Characteristics.

H. T. Florence, Sales Engineer, The Cleveland Crane and Engineering Company—Welding Overhead Traveling Electric Cranes.

A. E. Gibson, Vice-President, The Wellman Engineering Company—Welded Heavy Mechanical Equipment.

The meeting proved to be most interesting and there were about one hundred in attendance.

It is planned to have Mr. Charles H. Jennings of The Westinghouse Electric and Manufacturing Company as the speaker at the May 8th meeting. He will talk on "Welding Cast Steel and Cast Iron."

DETROIT

On April 17th a joint meeting of the AMERICAN WELDING SOCIETY, American Society of Mechanical Engineers and the American Society for Metals was held at the Detroit Edison Company's Building, Detroit. Dinner was served in the restaurant from 6 to 7 P.M. after which an after dinner "movie" was shown in the Auditorium.

Mr. W. S. Knudsen, Executive Vice-President of General Motors, presided at the Technical Meeting which followed. The dinner attendance was 200; that in the Auditorium for the meeting proper close to 600.

Mr. Knudsen related some of his early experiences dating back 29 years when Paul Dubois came from France to Buffalo to make some of the earliest installations of acetylene welding outfits in the country. Mr. Knudsen was designated by his company to assist Mr. Dubois—all conversations in French—and when Dubois got homesick and decided he must return home with the installation still unfinished, considerable diplomacy—and much beer—was required to avert serious difficulty. Of course, the early installations were very crude and every now and then large holes in the roof had to be repaired.

In 1918 Mr. Knudsen was in full charge for the Ford Motor Company, of the construction of the "Eagles," U. S. Destroyers, to be used on the Atlantic to convoy troops to France. The construction of these vessels involved the assembly of complicated warped surfaces which gave no end of trouble to the men detailing the steel for rivets. Mr. Knudsen introduced arc-welding into the fabrication of these irregular shapes and a great help it proved to be even in those days of bare wire and inexperienced operators.

Mr. Knudsen has since then enthusiastically enlarged the use of Resistance Welding in automobile body construction, witness the large flash-welded assemblies including the famous turret-top of present day General Motors cars.

After this interesting sketch of personal experiences—which, incidentally, show how well versed the speaker is in the intimate details of the welding art in all its phases—Mr. Knudsen introduced the speakers of the evening, Dr. D. S. Jacobus, President A. W. S. and Dr. Comfort A. Adams, Director, American Bureau of Welding.

Dr. Jacobus first gave a comprehensive history of the welding codes initiated by the Welding Committee of A. S. M. E. He disclosed the large amount of research work and of fact gathering that preceded the formulation of those codes, the insistance of insurance companies that such codes be enacted and the objection to the codes from various sources after they were formulated.

The large part being played by the A. W. S. Committees now in session in the formulation of Standards and Codes for the various applications of welding was described. Dr. Jacobus made it plain that there was no antagonistic spirit in the activity of these committees, but very much the opposite and he urged his hearers not to wait until codes and standards were written to start objecting to them but to lend all possible assistance to the standing committees and advise them of all desirable and undesirable provisions during their formulation.

Dr. Jacobus then gave an interesting account of the Babcock & Wilcox penstock tubes at Boulder Dam. By means of excellent slides he showed the fully equipped shop built right at the site in which the huge 30 ft. pipes up to $2^5/_8$" thick are rolled, arc welded and X-rayed. He pictured the handling of these gigantic units, 24 ft. long, weighing each 180 tons, their lowering to position and their pin assembly to other sections. The speaker fully explained, from personal contact and experience with the work, all the details of fabrication and erection in the clearest manner and drew, at Mr. Knudsen's request, a standing vote of thanks for his most interesting presentation.

The Chairman then introduced Dr. Comfort A. Adams of Harvard University. Dr. Adams, after rapidly tracing the development of resistance welding since its discovery by Dr. Elihu Thomson at Lynn, Mass., enumerated the various types of resistance welding, their characteristics and the principal applications. He gave the reasons that govern the choice of each type of resistance welding, the underlying principles that must be recognized in the design of the machines and many of the pitfalls that must be avoided. By means of carefully selected slides, he made clear the concentrations of current which have been observed at the points of electrodes, as well as the method of distribution of the current in or around them. Other slides showed the result of incorrect timing or unsuitable current in resistance welds, while the speaker drew attention to the interrelation of timing and current concentration for successful results. A series of slides were then presented relating to the welding of stainless steel, exemplified particularly by the construction of the "Burlington Zephyr."

LOS ANGELES

The regular meeting of this Section was held at New Hotel Rosslyn on March 21st and was well attended. 83 members and guests were present. Mr. Don Cameron, Sales Engr., Union Oil Company, started the meeting with an animated picture with sound effects and then gave a talk on the discovery and history of Triton Oil. This was demonstrated in a laboratory set-up by taking real thick crude and treating it the same as in the refinery and coming up with some nice clear oil that lacked one more treatment to make it first class Triton. He gave a moving picture and talk on the refinery at Oleum which was very interesting to all present. His numerous charts were interesting because they showed the difference this Propane solvent treatment made to Oil.

Mr. Earl Gard, Development Engr., Union Oil Co., gave a very interesting paper on Physical Properties of Steel at Sub-Zero Temperatures and how they arrived at the best procedure to weld these steels. This talk was illustrated with slides and charts and thoroughly explained by Mr. Gard.

Mr. W. L. Rifenberick, Chief Engr., Gasoline Department, Consolidated Steel Corp., gave a talk on their part of the manufacture and tests of various vessels they built for the Union Oil Company's refinery at Oleum. His talk was illustrated with moving pictures of various parts of their plant and apparatus used in the manufacture of above units.

Mr. James T. Kempt, Service Engr. of the American Brass Company, talked on the more recent information concerning the strength of welds in non-ferrous materials. Mr. Kemp had many interesting samples of long-arc copper welding that he showed around and explained necessary steps required to accomplish this class of welding.

NEW YORK

A joint meeting of the New York Chapter of American Society for Metals and New York Section of AMERICAN WELDING SOCIETY was held on April 22nd in the Hotel Pennsylvania. Mr. Leon C. Bibber, Senior Welding Engineer, Bureau of Construction and Repair, U. S. Navy Department, spoke on "Some Metallurgical Aspects of Welding."

The May meeting of the New York Section will be held on the 14th in the Engineering Societies Building. Dr. W. M. Mitchell, Metallurgical Engineer, Subsidiary Manufacturing Companies, U. S. Steel Corporation, will preside, Mr. H. L. R. Whitney, Chief Engineer. The M. W. Kellogg Company, will speak on "Corrosion Resisting Steels in the Petroleum, Chemical and Allied Industries"; and Mr. Edmund Peremi, Vice-President of the General Bronze Corporation, will speak on "The Use of Stainless Steels in Architectural Work." Discussion will follow.

NORTHERN NEW YORK

The Northern New York Section sponsored a joint meeting with all the local technical societies, April 18th, on the subject of "Arc Welding and the Boulder Dam Project" in Rice Hall, General Electric Company, Schenectady. Approximately 360 were present. Dr. J. C. Hodge, Metallurgist, and Mr. J. E. Treanor, General Superintendent, of the

Babcock & Wilcox Company, discussed the project as a whole, and the details of welding and fabricating the large diameter penstocks, with the aid of movies and slides.

SAN FRANCISCO

A very interesting meeting of the San Francisco Section was held on April 26th. Mr. Von Planck, Chief Metallurgist of the Columbia Steel Co. spoke on "New Developments in Steel Manufacturing." The Columbia Steel Co. also showed a film of two reels showing the construction features of Boulder Dam.

Annual Report of President, Year Ending March 31, 1935

To Members of the AMERICAN WELDING SOCIETY:

As prescribed by the By-Laws, the following report covering the activities of the Society for the administrative year ending March 31, 1935, is here submitted:

Finances

In the aggregate, gross income shows a general increase of 2.6% over the preceding year, as compared with a 1% increase experienced in the past fiscal period. This gain is distributed as follows:

Membership Dues, increase	$1,887.65	20%
Journal Advertising, decrease	865.00	18%
Subscriptions, decrease	178.39	6.5%
Printed Matter and Sundries, decrease	275.60	15%
Total Gain	$ 568.66	2.6%

Expense shows an aggregate increase of $1,379.44. Of this increase $201.04 is accounted for by the Year Book which was printed this past fiscal year and not in the year preceding. This leaves an increase of $1,178.40 accounted for as follows:

	Increase
Journal Expenses	$ 256.27
Fall Meeting Expense	267.61
Annual Meeting Expense	29.97
Membership Campaign and Promotion	371.70
Miscellaneous Administrative Expense	252.85
	$1,178.40

The net profit of $169.17 when compared with the profit of $979.95 had in the previous fiscal year, shows a decrease of $810.78. It cannot be said with certainty that any one factor was of greatest effect in this result, since almost all items of income and expense have shown fairly wide fluctuations. For example, advertising income alone fell $865; net Fall Meeting income fell $434.83; the Year Book cost $201.04.

Membership

Your Membership Committee is pleased to report an increase in membership for the year ending March 31, 1935. During this period 376 new members have been added to our rolls and 137 dropped, leaving a net gain of 239 new members. Our present membership is 1614.

This is the largest membership we have had during the existence of the Society, but in order that you may have a true picture your committee wishes to advise that 443 of these have been delinquent more than six (6) months. The largest gain has been in the Associate Member grade with annual dues of $10.00, the increase in this group being 83%.

During the year we have added four Sustaining Members. This increase in Sustaining Membership has been due largely to the Cleveland Section's activities. Your Committee has been conducting an active membership campaign during the past two months. 100 new members have thus far been secured but it is too early to predict the final outcome of the drive.

Promotional meetings were held in Baltimore early this year and on March 29, 1935, there was sufficient interest to elect officers. All requirements for the organization of a section having been fulfilled, the group has applied for authority to operate as the Baltimore Section.

Through efforts of the Chicago Section two promotional meetings have been held in Milwaukee and temporary officers elected with the idea of building up the membership to a sufficient number to apply for a charter.

Although statistics covering membership show a fairly satisfactory state of affairs, the Membership Committee believes that if the proposed Welding Manual or Handbook were ready, it would be very helpful in inducing new members to sign up.

If it is desired to put the activities of the WELDING SOCIETY on a completely self supporting basis from membership dues the Handbook and other inducements are absolutely necessary.

Sections

Most of your Sections have been active during the past year. In addition to holding regular meetings the following activities are worthy of mention:

Philadelphia Section ran a lecture course resulting in an increase of 100 new members. Demonstrations of types of welding and heat treatment were shown in connection with a joint meeting with the Franklin Institute.

Cleveland Section has been active in increasing its membership, particularly in the Sustaining grade.

Chicago Section assisted in the formulation and adoption of proposed new Chicago Building Code. A special meeting attended by over 400 was held in Milwaukee in an effort to organize a Section in that city.

Detroit Section has concentrated on building up its membership. It has assisted the younger members in obtaining employment. It has laid foundation for building up a larger and stronger Section with an increased enrolment from the Resistance Welding field.

New York Section held a number of very successful joint meetings as well as a "Navy Night," with an average attendance of about 300. It is considering an extension course for welding operators.

Boston Section assisted in opposing detrimental legislation. It held several joint meetings and inspection trips to various plants.

San Francisco and Los Angeles Sections assisted in the Correlation of Test Requirements for Qualifying Welding Operators.

In St. Louis effort is being made to reorganize the St. Louis Welding Society as a Section of the AMERICAN WELDING SOCIETY.

Your Pacific Coast Divisional Vice-President reports that negotiations have been under way for quite some time for the establishment of new Sections in Salt Lake City and Denver. Correspondence in connection with these will be turned over to the new Divisional Vice-President, and it is hoped he will carry them forward to a successful conclusion.

The Middle Western Divisional Vice-President reports that effort has been made to establish a Section in Toledo which might be brought about this Season.

Journal

Material improvements have been made in the appearance of the JOURNAL and its layout. At present the JOURNAL serves the technical members of the SOCIETY very well, but unfortunately, because of lack of funds, it does not completely meet the needs of those concerned primarily with the promotion of welding. An ideal arrangement would be to have two books, one the *Welding Journal*, a magazine of a popular and promotional nature devoted extensively to pictorial representations, news items and current developments, and the second, the *Transactions of the AWS* devoted largely to important papers, codes, standards and specifications issued by the SOCIETY and the research reports of the American Bureau of Welding.

532 pages were published as compared with 504 pages in the previous years. These were divided as follows: 320 technical pages, 65 editorial pages and 147 advertisements and circular matter. It has not always been possible to maintain the new departments inaugurated last year, largely again, because of lack of funds. In spite of adverse business conditions, the JOURNAL continues to be operated at a profit and contributes in a considerable measure to the maintenance of the SOCIETY activities.

Meetings

The Fall Meeting held in New York, October 1 to 5 in conjunction with the National Metal Exposition, was one of the most successful. The exposition with 19 exhibitors of welding apparatus and supplies and a number of important users of welding, was viewed by about 25,000. Over 500 members and guests of the SOCIETY registered, attended and participated in the technical sessions. The papers covered a wide range of applications. The outstanding feature of these sessions was the numerous reports on researches completed at university, governmental and company laboratories. There were also many technical papers dealing with welding applications.

The technical sessions were supplemented by two inspection trips. The outstanding social event was the Stag Dinner attended by 250 members and their guests.

The Annual Meeting this year, as in the previous year, will be a one-day Business Session including a Business meeting in the morning, American Bureau of Welding and Committee meetings in the afternoon, and a Directors' meeting in the evening. Such arrangement permits the giving of major efforts to the success of the Fall Meeting.

Changes in By-Laws

During the year Amendments of Article IV, Sec. 8, Article VII, Sec. 1 (e), and addition of Sec. 2 to Article VII, received majority approval and are now in effect. Amendments of Article I, Sec. 2, Article II, Sec. 1 and Article III, Sec. 3 (proposed in the regular manner and having received approval of Board of Directors), have been submitted to the membership for letter ballot vote thereon.

Society Technical Committees

The following work has been completed during the year.—Reports have been approved, and in most cases published in the SOCIETY JOURNAL: Code 1, Part A, Code for Fusion Welding and Gas Cutting in Building Construction, 1934 edition; Code 2 for Resistance Welding of Structural Steel in Building Construction; Rules for Fusion Welding of Hulls and Hull Parts of Marine Code for Fusion Welding and Gas Cutting; Tentative Rules for the Fusion Welding of Gravity Tanks, Tank Risers and Towers; Revised Fusion Welded Symbols; Procedure in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles; Code for Fusion Welding and Flame Cutting in Machinery Construction.

A new project on Design of Welded Penstocks has been initiated during the year by the appointment of a committee with Dr. W. F. Durand as Chairman composed of the highest authorities on the subject. Any report rendered by this committee it is felt, would be acknowledged as a classic by the engineering world.

The work of the other committees may be summarized briefly as follows. More detailed reports of the activities of these committees are available in the SOCIETY office to any one interested.

Committee on Welding Bridges

In the early part of the year the Committee personnel was determined, and the personnel canvassed for views on organization for the work assigned. In the ensuing days your Committee concerned itself with collection of specifications, codes, published articles and other information for use of committee's work. During the SOCIETY'S Fall Meeting a meeting of your Committee was held, work was laid out and the following sub-committees named: (1) Assembling of existing specifications, codes and reports for use of Committee; (2) Preparation of specifications on new bridges; (3) Preparation of specifications on strengthening and repairing existing bridges; (4) Preparation of specifications on technique and equipment for flame welding and cutting; (5) Preparation of specifications for methods and procedure in inspection; (6) Formulation of recommendations of A.A.S.H.O. specifications; (7) Editing—Preparation of draft of specifications on basis of material furnished. The assembled data were furnished to the interested sub-committees, and the sub-committees proceeded with the development of the topics assigned to them. At a meeting in January, the work of the sub-committees was reviewed and additional sub-committees were named. All sub-committees were urged to expedite the development of their respective topics. Sub-committees appointed to confer with representatives of the A.A.S.H.O. on the Welding Specifications formulated by that organization, held a conference in Washington on January 29th. At the March 30th meeting of your Committee consideration was given to sub-committee reports. It is planned to meet in Philadelphia on April 29th to discuss the remainder of the sub-committee reports. It is hoped at that time to complete the detailed discussion of all sub-committee reports and to turn the data over to the editing sub-committee who will then be in a position to consult the same, prepare and submit the entire report to your Committee. Your Committee Chairman wishes at this time to express his appreciation for the loyalty and whole-hearted cooperation of the Committee membership.

Committee on Rules for Welded Construction of Oil Storage Tanks

Several meetings of your Committee have been held and the work is progressing rapidly toward a preliminary report on a tentative code. This Code will take into consideration many different types and forms of tank construction and will be so formulated as to cause no interference with the ingenuity of engineers in their design work. The new code will furnish data to assist engineers in the production of welded tanks that will be pre-eminently safe and that will also give satisfactory service.

Committee to Correlate Tests for Qualification of Welding Operators

Your Committee appointed early in 1934 to investigate existing practices in the qualification of operators of welding equipment and to correlate, if possible, the many and varying codes of rules therefor, held an organization meeting at the time of the Fall meeting of the SOCIETY and laid plans for the difficult task before it. At that meeting preliminary consideration was given to two recommended standard qualification test codes that had been submitted by the San Francisco and Los Angeles local sections, and later on a letter was drafted by the Committee and sent to your president, expressing its opinion on the test methods therein proposed.

The efforts of your Committee to obtain agreement on a plan of uniform qualification rules has been beset with difficulties. There has been emphatic evidence of the desire on the part of many to greatly simplify and abbreviate the qualification test procedure in order to save expense; on the other hand the regulatory bodies and authorities who are responsible for the welding work covered have resisted too great an abbreviation of the test requirements. Between these two extremes there seemed, for a long time, to be no easy compromise, until at a recent meeting the modified plan of separating the process qualification from the tests for qualifying the welders was proposed. Now a revised draft of the proposed code of uniform tests has been prepared and is in the hands of the Committee members.

This new development is the result of the inevitable consideration that any test schedule for qualifying a welding operator must, of necessity, embrace the welding process to some extent. In order to qualify, an operator must be provided with suitable welding equipment and materials; the best and most experienced operator may fail in his tests if not provided with a suitable process to demonstrate his fitness. It is therefore the intent of the present proposal of your Committee to place the tests on a revised basis wherein the welding process is first qualified to determine its ability to meet any specified requirements, and then by means of a few inexpensive tests, to determine the ability of a welding operator to properly apply that process.

It is the hope of the Committee that this modified plan will serve as a basis for bringing order out of the present chaotic and unsatisfactory condition.

Committee on Formulation of Procedure for Welding in the Construction of Railroad Rolling and Stock and Appurtenances Thereto

Your Committee has had but one meeting at which time the scope of activities of the Committee was discussed. The Committee now plans to meet regularly, the next meeting being tentatively set for April 26th in Chicago.

Revision of Nomenclature, Definitions and Symbols

Your Committee is engaged in a revision of bulletin published in November 1929. The revison is being undertaken by three

sub-committees, one on Chart under the supervison of Mr. Llewellyn, the second on Nomenclature and Definitions under Lieut. Broberg and the third on Symbols under the supervision of Mr. L. S. Bibber. A sub-committee on "Classification" under the Chairmanship of H. W. Samson has practically completed its work.

Committee on Welding in Marine Construction

1. Your committee has under preparation a comprehensive marine code consisting of a number of parts. The two following parts have been completed and approved by the Board of Directors of the SOCIETY:

Part B—Rules for the Fusion Welding of Drums or Shells of Marine Boilers and Pressure Vessels.

Part D—Rules for the Fusion Welding of Hulls and Hull Parts.

2. Part B has been used as a basis for the welding requirements embodied in the revised Rules of the U. S. Bureau of Navigation and Steamboat Inspection and will be adopted as the rules of this body. Your President who is the Chairman of our Committees' Boiler Sub-Committee which drafted these rules recommended that its publication be deferred pending the issuance of the Bureau of Navigation and Steamboat Inspection Rules, and the coordination of minor differences between the two sets of rules. This sub-committee is working on the other parts of the A. W. S. Marine Code dealing with Boilers.

3. Part D was published in the February issue of the JOURNAL of the SOCIETY. The other parts of the Code dealing with Hull Construction are being completed by the Hull Sub-Committee under the chairmanship of Mr. C. W. Bryan, Jr.

Filler Metal Specifications

A meeting of the Committee is being held during the Annual Meeting for the consideration of adoption or need for revising the present Specifications. The Committee will then participate in a joint conference with the A.S.T.M. and at that time offer recommendations for revision and expansion of the Filler Metal Specifications.

Committee on Building Codes

The revision of Code 1, Part A, for Fusion Welding and Gas Cutting in Building Construction was successfully accomplished in January 1935, having received the approval of the Board of Directors. It has been published in the SOCIETY JOURNAL and in pamphlet form. Code 2 for Resistance Welding of Structural Steel in Building Construction was approved by the Society in February 1935 and it will shortly appear in printed form. The code restricts the application of resistance welding those members (such as joists, light trusses, stair stringers and similar parts) which, by reason of their shop fabrication in multiple quantities, can be subjected to definite qualification tests. The allowable working stresses coincide with those specified in Code 1, and a minimum factor of safety of 3 is required for the weakest member or joint of any product manufactured by resistance welding machines.

Upon the request of the Philadelphia City Planning Commission, information on resistance welding practices was supplied in the form of copies of Code 2 (Resistance Welding Code). The State of Pennsylvania, Department of Internal Affairs, requested and was furnished with copies of Code 1, as well as supplementary information regarding the application of fusion welding to structural steel. The Department is working upon a proposed code for building operations in the State of Pennsylvania. Copies of Code 1 were supplied to members of the Chicago Section to assist them in preparing welding regulations for inclusion in the proposed revised Building Code. At the request of the Building Department, code data were supplied for inclusion in the Building Code of the City of New Britain, Conn.

Information was supplied to Panama Canal Department, U. S. Army, regarding the application of fusion welding to buildings under their jurisdiction. Canadian Engineering Standards Association is now engaged in the preparation of a code for fusion welding in the Dominion of Canada. They have requested data from us and will keep us in touch with developments along this line.

The Committee reports the resignation on February 7, 1935, due to pressure of other activities, of its Chairman, Mr. H. H. Moss. Mr. G. D. Fish has been appointed to succeed him.

Committee on Welding Code for Pressure Piping

The final draft of the Code which was formulated by your Committee and which was formally presented for public hearing and approved by the Board of Directors of the SOCIETY is to be incorporated as a part of the American Standard Association's general code for Pressure Piping. The welding section is to be noted as Section 5 of the Pressure Piping Code.

The Pressure Piping Code has been finally approved by letter ballot of the Sectional Committee formulating it and by the A.S.M.E. which is the sponsoring body. It has also been approved by the American Standards Association and is now in the hands of the printer.

Definite assurance has been given that the Code for Pressure Piping will be published and released for distribution not later than April 30, 1935.

American Bureau of Welding

During the year there has been published under the auspices of the Committees of the American Bureau of Welding the following reports:

Tensile Tests of Welded and Riveted Structural Members—R. P. Davis and G. P. Boomsliter, April 1934.

Welding of Structural Nickel Steel—W. L. Warner, June 1934.

The Nature of the Bond in Bronze Welding—A. A. Jackman, July 1934.

An Examination of Welds Made under Field Conditions for High-Pressure, High-Temperature Steam Station Piping—A. E. White, D. H. Corey and C. L. Clark, September 1934.

Notes on the Fatigue Testing of Welds—J. H. Zimmerman, September 1934.

Historical Developments and Future Possibilities of Welding—D. S. Jacobus, October 1934.

Resistance Welding of Thin-Gage Duralumin—N. F. Ward, December 1934.

Some Measurements of Residual Stresses in Arc-Welded Steel Plates—R. E. Jamieson, December 1934.

An Investigation of Welded Seat Angle Connections—Inge Lyse and Norman G. Schreiner, February 1935.

A Photoelastic Study of Bending in Welded Seat Angle Connections—Inge Lyse and Douglas M. Stewart, February 1935.

Corrosion-Fatigue Study of Welded 18:8 Stainless Steel—W. E. Harvey, A. J. Ciastkewicz and F. J. Whitney, Jr., January 1935.

Effect of Peening on Physical Properties of Welds and Stress Relief—O. M. Harrelson, Preprint of Fall Meeting Papers.

Reorganization of the American Bureau of Welding

Owing to the fact that the National Research Council finds it no longer possible to sponsor the work of the Bureau and to contribute to its support as it has in the past, and owing to the fact that most of the agencies now cooperating in the work of the Bureau are inactive in that connection, there seems to be no good reason for continuing the present form of organization as such. It has been proposed therefore to make the present work of the Bureau an integral part of the activities of the AMERICAN WELDING SOCIETY.

Your Committee on Reclassification of Membership of the AMERICAN WELDING SOCIETY considered this whole matter very carefully and recommended that the present Bureau be abolished and that the SOCIETY appoint a welding research committee on which would serve the chairmen of the research committees (Fundamental and Structural), a representative of the National Research Council, a representative of Engineering Foundation and five others to be appointed by the president. The committee would have the same status as other standing committees of the AMERICAN WELDING SOCIETY.

This matter was duly considered by the Board of Directors of the AMERICAN WELDING SOCIETY and while the Board generally approved this recommendation, it felt it desirable to ascertain the wishes of the National Research Council and to permit a discussion of this whole situation by members of the American Bureau of Welding.

After due deliberation the National Research Council indicated that it was necessary to limit its expenditure in every possible way, which made it impossible for them to remain a joint sponsor and to contribute toward the maintenance of the American Bureau of Welding as in the past. On behalf of the National Research Council, Dr. Bowman expressed his regret that it was necessary to make such a decision and indicated that the Council appreciates the high

quality of the work done by the Bureau.

This matter will be considered at a meeting of the American Bureau of Welding on April 25th.

Special Committee on Reclassification of Membership and Returns to Sections on Membership Dues

After the President had an opportunity to discuss these matters with a number of the Sections and had informed the Committee of the results, your Committee prepared and offered definite recommendations which, having received the approval of the Board of Directors, were submitted to the membership.

Manufacturers Committee

Your Committee gave consideration to exposition arrangement for 1935 and the future. It recommended that for 1935 your SOCIETY participate in the National Metal Exposition to be held in Chicago. A small sub-committee is working on the matter of future expositions and hopes to have sufficient information to serve as a guide in connection with future arrangements. On the 1935 exposition the Committee has arranged so that your SOCIETY will receive a 15% return on gross receipts from the sale of space to exhibitors of welding equipment and welded products, with a minimum guarantee of $1000; also that your SOCIETY will be allowed a voice in selection of location of exposition and on entertainment features and inspection trips.

Convention Committee

Your Committee is handling arrangements for the Fall Meeting to be held in Chicago, the week of September 30th, in conjunction with the National Metal Exposition. The Palmer House has been selected for Headquarters, and the Chicago Section has signified its pleasure at being host and its willingness to do everything possible to help make the meeting a success.

Legislative Committee

Your Committee has given attention to, and rendered assistance in opposing the adoption of legislative bills detrimental to welding introduced in the states of Massachusetts and Colorado.

Representation on Other Technical Societies

Your SOCIETY has continued to participate in the activites of the following organizations: ASME Boiler Code Committee; ATA Way and Structures Committee No. 6 on Standard Specifications for Welding Rods; American Marine Standards Committee; ASA Sectional Committees on Electrical Definitions, Electric Welding, Protection of Heads and Eyes of Industrial Workers, Graphical Symbols on Drawings, Development of Ventilation Code, Safety Code for High Pressure Piping, Safety Code for Construction Work, Work in Compressed Air; ASTM Committee A1, Sub-Committee XXI dealing with Specifications for Steel for Fusion Welding and dealing with Welding Wire Specifications; Sub-Committee No. 5 on Wrought Copper and Copper Alloys; Merchants Association Advisory Committee on Revision of New York City Building Code; Executive Committee of National Board of Boiler and Pressure Vessel Inspectors; ASM Recommended Practice Committee and National Research Council.

Space does not permit giving a detailed account of all of these committees, although reports may be found in the files of the SOCIETY by any one interested.

Special recognition is given to the work of the following:

Conference Committee with ASME Boiler Code Committee

The past year of 1934 has shown increased activity in the work of the A.S.M.E. Boiler Code Committee and four problems relating to the application of fusion welding in the pressure vessel industry have been submitted to your Conference Committee. The numbers and subjects of these problems are as follows:

No. 39—Revision of Bend Test Requirements in Par. U-69
No. 40—Test Plate for Class I Welded Pressure Vessels
No. 41—Full Section Test Specimen
No. 42—Preparation of Plates for Welding Class I Vessels.

Problems 39, 40 and 41 involved questions that had arisen in connection with the revisions in 1934 of the welding rules in the A.S.M.E. Boiler Construction Code. Careful consideration was given to these questions and your Committee was able to assist the Boiler Code Committee in rendering important decisions thereon.

Problem 42 was one of the most important questions which the Conference Committee has been called upon to consider in its recent work, as it is concerned with a much discussed question of acceptability of welding on gas cut plate edges. Recently the practice of shaping the welding edges of plates by gas cutting machines has become very prevalent, but inspectors who were ignorant of the results of the gas cutting process have been inclined to treat gas cut edges in the same manner as sheared edges and have required the machining or chipping of the gas cut edge down to bright metal. The recommendation of our Conference Committee has assisted the Boiler Code Committee in determining the facts and establishing the conditions under which welding on such gas cut edges is permissible.

ARA Tank Car Committee

The Committee held two meetings at which our representative, Mr. J. J. Crowe, was present, the first in New York on April 5, 1933; at this meeting plans were made for collecting and presenting evidence to the I.C.C. on the merits of welding as applied to the construction of tank car tanks and the second meeting was held in Washington on September 4, 1933, to review the evidence collected.

On September 5th, 6th and 7th the evidence was presented at a hearing of the I.C.C. with Director Bartel in the chair, assisted by Messrs. Doyle and Fielder.

Our representative presented a prepared statement favoring the use of fusion welding for the construction of the tanks and was cross-examined as to the limitations of welding.

Construction of Marine Buoys

There has been only one meeting of this Committee and at that meeting our representative was present by proxy.

The problems involved in buoy design were discussed and a sub-committee was appointed to prepare a draft of a code to cover the construction of welded buoys, This code to include a method of qualifying welders and procedure for inspecting and testing the finished product.

ASTM Sub-Committee B 5

Your representative on this Committee reports that considerable progress has been made in the development of welding procedures for welding bronze bridge or expansion plates to the cast iron or steel base metal. Considerable progress has also been made on the problem of coating wear surfaces with Phosphor Bronze weld metal using the metallic arc or the carbon arc method of welding.

National Board of Boiler and Pressure Vessel Inspectors

An important action of the National Board during the year was the approval, in cooperation with the National Bureau of Casualty and Surety Underwriters, of a set of rules for the repair by welding of existing steam boilers.

The National Board has also taken an active interest in the much discussed question of a qualification of welding operators which has, of course, an important influence on the work of its authorized inspectors.

Noteworthy Items

Visits to Sections

Your President visited the out of town local Sections, conferred with the officers and representative groups and made addresses illustrated by lantern slides. The Sections visited given in the order in which the visits were made were as follows:

Los Angeles, California
San Francisco, California
Portland, Oregon
Philadelphia, Pa.
Pittsburgh, Pa.
Cleveland, Ohio
Boston, Mass.
Chicago, Ill.
Detroit, Michigan

Your President also addressed meetings in Hawaii and in Denver, Colorado. Information secured at these meetings will be brought before the Board of Directors.

A.W.S. Welding Manual

A suggestion that the SOCIETY issue a welding manual met with approval. The plan proposed is to have some fifty or more chapters prepared by outstanding authorities. A suggested list of subjects and authors was forwarded to those invited to prepare the various items. Nearly all invited to prepare the items have accepted.

It was decided not to start the work until the full amount required for the publication of the manual is pledged.

It has been proposed to set aside $2.00 from the dues of every new member for a period of one year and to sell copies of the manual to non-members at $5.00 each.

A number of companies have expressed their willingness to underwrite the enterprise to the extent of $100 either by a cash payment or by ordering 25 of the books at $4.00 each.

An additional list of the over 200 prospective contributors was prepared and after consideration it was decided to ask for $50 to $100 contributions. Letters have been sent to all of those on the prospective list and it is hoped that the responses will be as favorable as in the case of those previously approached. An Editorial Committee has been appointed consisting of Messrs. Adams, Llewellyn, Obert and your President to cooperate with Mr. Spraragen as Editor in the preparation of the manual.

Cooperation and Assistance Rendered International Association

British Iron and Steel Institute Welding Symposium in London in 1935—Society suggested subjects and authors from the United States and assisted in securing these authors.

Respectfully submitted
D. S. Jacobus
President

Special Offer

While supply lasts you can obtain set of two Instruction Manuals at $2.75.

Set includes:
"Manual of Electric Arc Welding" by E. H. Hubert (Regular price $2.00)
and
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